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Promoting best practice in infection prevention in general surgery through education.

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PROMOTING BEST PRACTICE IN INFECTION PREVENTION IN
GENERAL SURGERY THROUGH EDUCATION

A THESIS PRESENTED TO

THE ROYAL COLLEGE OF SURGEONS IN IRELAND

FOR THE DEGREE OF
DOCTOR OF MEDICINE

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List of abbreviations

CDC Centre of disease control and prevention

CFU Colony forming units

CPD Continuing professional development

CRBSI Catheter-related bloodstream infection

CVC Central venous catheter

HCAI Healthcare associated infection

HISPS Hospital infection society prevalence survey

HPSC Health protection surveillance centre

HSE Health service executive

HTML Hypertext mark-up language

ICR Intelligent character recognition

ICU Intensive care unit

MRN Medical record number

MRSA Methicillin resistant staphylococcus aureus

MySQL My structure query language

NCHD Non-consultant hospital doctor

NHS National health service

NICE National institute for clinical excellence

NNIS National nosocomial infections surveillance

OMR Optical mark reading

PHP Hypertext pre-processor

PVC Peripheral venous catheter

RSS Really simple syndication

SIGN Scottish intercollegiate guidelines network

SSI Surgical site infection

SSSL Safe surgery saves lives

TPN Total parenteral nutrition

WHO World health organisation

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Abstract

Introduction

Surgical patients are particularly at risk of healthcare associated infection (HCAI) by virtue of the presence of a surgical site leading to surgical site infections (SSI) and because of the need for intravascular access resulting in catheter-related bloodstream infection (CRBSI).

Methods

A two-year initiative commenced with an initial audit of surgical practice which was used to inform the development of a targeted educational initiative by surgeons specific for surgical trainees. Parameters assessed during initial and repeat audits after the educational initiative included intra- and post-operative aspects of the prevention of SSI as well as the care of peripheral venous cannulae (PVC) in surgical patients.

Results

The proportion of prophylactic antibiotics administered pre-incision across 360 operations increased from 30% to 59.1% ($p<0.001$). Surgical site dressings were observed in 234 patients, with a significant decrease noted in the percentage tampered during the initial 48 hours post procedure (6.2% vs. 16.5%, $p=0.030$). A total of 574 PVC were assessed over the two year period. Improvements were noted in the proportion of unnecessary PVC *in-situ* (24.4% vs. 37.9%, $p<0.001$), PVC *in situ* for more than 72 hours (3.1% vs. 10.6%, $p<0.001$) and PVC covered with clean intact dressings (97.6% vs. 87.3%, $p<0.001$).

Conclusion

Significant improvements were seen in surgical practice in SSI and CRBSI prevention through a focused educational programme developed by and for surgeons.

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Chapter One

Introduction

1.1. Healthcare associated infections

Healthcare associated infection (HCAI) causes considerable morbidity and mortality. The total number of patients acquiring HCAI in the European Union every year is estimated at 3 million, with 50,000 deaths per year as a consequence (Lyon 2004). The recent Hospital Infection Society Prevalence Survey (HISPS) of HCAI noted a prevalence of 4.9% in Irish hospitals overall, with the figure increasing to 6% in tertiary referral centres (Harris, Morgan et al. 2008). The third most common HCAI system infection was surgical site infection (SSI), accounting for 14.5% of HCAI overall. Other HCAI system infections were gastrointestinal (20.6%), urinary tract (19.9%), respiratory tract (14.1%), skin and soft tissue (10.4%) and primary bloodstream (7.0%) (Smyth, McIlvenny et al. 2008).

In North America extensive financial assessments calculate the costs of HCAs to be \$4.5-5.7 billion per year (Safdar and Abad 2008). To put this in an individual patient context, a recent U.S. study ascertained that the HCAI cost per case was a minimum of \$4,644 (Kilgore, Ghosh et al. 2008) but for bloodstream infection, the costs were double or more at \$10-20,000 per patient (Kilgore and Brossette 2008).

Surgical patients are particularly at risk of HCAI by virtue of the presence of a surgical site leading to SSI, the need for intravascular access resulting in catheter-related bloodstream infection (CRBSI), and sub-optimal professional practice, specifically hand hygiene amongst surgeons and other healthcare professionals.

1.1.1. Surgical site infection

It was not until the 1860s when Joseph Lister introduced the principles of anti-sepsis that postoperative infectious morbidity decreased substantially. However, SSIs remain a major clinical problem today in terms of morbidity, mortality, length of stay and hospital costs (Kirkland, Briggs et al. 1999; Leaper, Burman-Roy et al. 2008).

In the hospital where this study is carried out there is no active SSI surveillance programme. As a result there is very limited data on the existing rates of SSI in the study hospital. Overall approximately 5% of patients undergoing surgery develop an SSI (Gottrup 2000). Surgical site infections are the second most common cause of HCAI (1996; Burke 2003). Between 2% and 5% of patients undergoing clean extra-abdominal surgery and up to 20% undergoing intra-abdominal operations will develop an SSI (Shojania, Duncan et al. 2001). The US Centers for Disease Control and Prevention (CDC) estimates that approximately 500,000 SSIs occur annually in the United States (Wong 1999). Patients who develop SSIs are up to 60% more likely to spend time in an intensive care unit (ICU), five times more likely to be readmitted to the hospital, and two times more likely to die than are patients without an SSI (Kirkland, Briggs et al. 1999). Furthermore, overall care costs are substantially increased for patients who develop SSIs (Kirkland, Briggs et al. 1999; Hollenbeak, Murphy et al. 2002; Burke 2003; Perencevich, Sands et al. 2003).

Standard procedures for the prevention of SSIs include pre-operative patient preparation, appropriate prophylactic antibiotics, careful and skilled surgical technique, intra-operative medical management and post operative surgical site or wound care (Mangram, Horan et al. 1999).

The use of surgical attire (i.e. scrub suits, caps, masks, gloves and gowns) is generally strictly regulated, as is the operative environment (Mangram, Horan et al. 1999). It has been shown that the microbial counts in operating room air are directly proportional to the number of people moving in the room (Ayliffe 1991). Most surgeons have a strict view on surgical attire, changing into scrubs as well as wearing appropriate caps and masks before commencing an operation. The number of people moving about in the operating room, while important, can be difficult to restrict as more personnel are required sometimes for complex or difficult procedures and many centers are also major referral centres with significant teaching commitments. Consequently, medical students are often attached to surgical teams, including while they are in the operating theatre. Procedures and protocols in the operating theatre to minimise infection have recently been reviewed (Woodhead, Taylor et al. 2002), but much of what occurs is based on tradition and ritual, rather than on well conducted trials.

Evidence in the literature suggests that the critical factor in determining post-operative infection rates, particularly SSI is the competence of the individual surgeon (Mishriki, Law et al. 1990; Mishriki, Law et al. 1991). Consequently best practice guidelines for SSI prevention also acknowledge the importance of surgical technique as a risk factor (Mangram, Horan et al. 1999; Guideline 2008; Leaper, Burman-Roy et al. 2008; NICE 2008). Issues such as gentle tissue handling to minimize trauma, the use of diathermy, maintenance of haemostasis, and adequate debridement, are stressed as influential in surgical learning and training to decrease SSI.

1.1.2. Catheter-related bloodstream infection

Catheter-related bloodstream infection accounts for 7% of all HCAs (Wisplinghoff, Bischoff et al. 2004). With short-term intravascular catheters (i.e. <10 days), most device-related CRBSI are from the insertion site and gain access extra-luminally (Cooper and Hopkins 1985). The variation in CRBSI can be categorized into specific intravenous catheter types: central venous catheters (CVC) account for 72%, peripheral intravenous catheters for 35%, and arterial catheters 16% (Wisplinghoff, Bischoff et al. 2004). Apart from the type and location (e.g. jugular versus femoral site for CVC) of the intravascular catheter, other risk factors for infection include underlying disease (e.g. diabetes mellitus), method of catheter insertion, and the administration of parenteral nutrition (Yilmaz, Caylan et al. 2007). The National Nosocomial Infections Surveillance (NNIS) system managed from the CDC in the U.S.A. reports a CRBSI rate of 5.7 per 1,000 catheter days(2000). Approaches to reducing this rate of CRBSI include minimizing the duration of catheter use, hand hygiene, the use of barrier precautions on insertion and the use of suitable skin disinfection, e.g. chlorhexidine (Pronovost, Needham et al. 2006).

1. 2. Factors associated with HCAI in surgical patients

The literature reveals a number of risk factors for HCAI in surgical patients. A number of patient-related risk factors have been associated with the onset of SSI, such as greater age, hypoalbuminaemia, immunosuppression and obesity (Pastor, Baek et al. ; Kaye, Schmit et al. 2005; Fiorio, Marvaso et al. 2006; Clements, Tong et al. 2007). There are also a number of procedure related risk factors which are discussed in the following section. These parameters are measurable and should practice be optimized with relation to these risk factors, the risk of

HCAI to surgical patients is significantly reduced. These procedure-related risk factors specifically relate to surgical site infection (SSI) and catheter-related bloodstream infection.

2.1 Surgical site infection risk factors

Risk factors for SSI can be subdivided into pre-operative, intra-operative and post-operative factors.

1.2.2. Pre-operative risk factors

Pre-operative risk factors include surgical hand antisepsis, appropriate surgical attire, removal of hair from the surgical site, draping of the surgical site and appropriate choice and timing of antibiotic prophylaxis.

1.2.2.1. Surgical hand antisepsis and attire

Micro-organisms causing SSIs come from a variety of sources including the surgical team. Surgeons wear sterile gloves in order to prevent the transfer of bacteria from their hands to patients. However, during surgery these gloves may become perforated and as a result it is necessary to have hands as free of bacteria as possible by hand antisepsis pre-operatively (surgical scrubbing) and double gloving, which also protects the operator from blood-borne viruses. Total bacterial counts on the hands of medical personnel range from 3.9×10^4 to 4.6×10^6 (Boyce and Pittet 2002). Since 1938, bacteria from the hands have been divided into two categories: transient and resident (Price 1938). Resident flora are attached to the deeper layers of the skin and are most resistant to removal. However these flora (i.e. coagulase-

negative staphylococcus and diphtheroids) are less likely to be associated with such infections. In contrast transient flora colonise the superficial layers of the skin and are more amenable to removal by surgical scrubbing. These flora are the organisms most frequently associated with HCAI.

A recent Cochrane review determined the effects of differing surgical hand antisepsis on the numbers of colony forming units (CFUs) of bacteria on the hands of the surgical team (Tanner, Swarbrook et al. 2008). This review reported that alcohol rubs are at least as effective as aqueous scrubs such as chlorhexidine iodine and povidone iodine in terms of the numbers of CFUs on hands. In 1990 Pereira et al assessed the number of CFUs using povidone iodine, chlorhexidine and alcohol based hand antisepsis (Pereira, Lee et al. 1990). The standard scrubbing duration in these studies comprised of a five minute initial scrub with subsequent three minute scrubs. This study demonstrated that subsequent scrub durations of 30 seconds (after the initial five-minute scrub) were less effective than the standard three minute scrubs when using chlorhexidine iodine. Furthermore both aqueous solutions were comparable to using an alcoholic disinfectant in reducing CFUs on surgeons' hands.

In addition it is recommended that the correct surgical attire should be worn by the surgical team. These include sterile gloves, sterile gown, a cap covering all hair, and a mask covering the nose and mouth (Mangram, Horan et al. 1999).

1.2.2.2. Hair removal from the surgical site

A further measure for SSI prevention is the removal of patients' hair in the surgical field using a razor. In the 1980s clinical investigations indicated that shaving increased SSI rates and that depilation or the use of electric clippers were preferable if hair removal was necessary (Cruse and Foord 1980). Subsequent studies have questioned this finding, reporting no significant differences in SSI rates between patients who had hair removal and those who did not have hair removal from the surgical site pre-operatively (Court-Brown 1981; Hoe and Nambiar 1985; Rojanapirom and Danchaivijitr 1992). However, more recently further studies have confirmed this association, reporting that clipping hair immediately before an operation has been associated with a lower risk of SSI than shaving or clipping the night before an operation (Masterson, Rodeheaver et al. 1984; Sellick, Stelmach et al. 1991). As a result 1999 guidelines from the CDC strongly recommend that hair should be removed at the surgical site if it is likely to interfere with the surgical procedure, and that if this hair is removed it should be done immediately before surgery and with clippers rather than a razor (Mangram, Horan et al. 1999).

1.2.2.3. Draping of surgical site

A further factor which may be associated with SSI is the correct prepping and draping of surgical patients pre-operatively. The patient's skin should be prepared by applying an antiseptic in concentric circles, beginning in the area of the proposed incision. The prepared area should be large enough to extend the incision or create new incisions or drain sites if necessary (Hardin 1997; Mangram, Horan et al. 1999). Most recent NICE guidelines do not recommend use of non-iodophor-impregnated incise drapes routinely for surgery as they may increase the risk of SSI. If an incise drape is required, they recommend use of an iodophor-impregnated drape unless the patient has an iodine allergy (NICE 2008).

1.2.2.4 Antiseptic preparation of surgical site

Published guidelines recommend the preparation of skin at the surgical site immediately before incision using an antiseptic (aqueous or alcohol-based) preparation: povidone-iodine or chlorhexidine are most suitable (NICE 2008). A recent study comparing chlorhexidine-alcohol with povidone-iodine solutions demonstrated that chlorhexidine-alcohol was significantly more protective against both superficial incisional infections (4.2% vs. 8.6%, $p=0.008$) and deep incisional infections (1% vs. 3%, $p=0.05$) (Darouiche, Wall et al. 2010). However if diathermy is to be used, it is essential to ensure that antiseptic skin preparations are dried by evaporation and pooling of alcohol-based preparations is avoided.

1.2.2.5. Antimicrobial prophylaxis

Surgical prophylaxis is an important adjunct used to reduce the microbial burden of intra-operative contamination to a level that cannot overwhelm host defenses (Sanderson 1993). Administration in the majority of scenarios is by intravenous infusion (Nichols 1989; Ehrenkranz 1993; Scher 1997). A recent meta-analysis supported the use of surgical prophylaxis as an effective intervention for the prevention of SSI across a broad range of surgical procedures (Bowater, Stirling et al. 2009). However, although surgical prophylaxis is a well established strategy for reducing the risk of SSI, the efficacy of the antimicrobial is optimized by correctly timing its administration in relation to surgery (Weber, Marti et al. 2008). Many studies have suggested that the optimal window for administration is between 30 and 60 minutes before the start of surgery (Tourmousoglou, Yiannakopoulou et al. 2008;

Weber, Marti et al. 2008). Guidelines in place in many countries contain no more than a general recommendation to administer surgical prophylaxis within 60 minutes of the start of the operation (Dellinger, Gross et al. 1994; Bratzler and Hunt 2006). Most recent NICE guidelines for example recommend administration at induction of anaesthesia (NICE 2008). Antimicrobial concentrations are unlikely to reach the minimum inhibitory concentration at the incision site to prevent SSI by commonly expected bacteria within a few minutes. It is generally recommended to give surgical prophylaxis within 60 minutes pre-operatively and preferably between 60 and 30 minutes before the start of the operation. This ensures that a bactericidal concentration of the drug is established in serum and tissues by the time the skin is incised (Classen, Evans et al. 1992).

1.2.3. Intra-operative risk factors

Intra-operative risk factors include surgical technique which encompasses method of incision, tissue handling, method of wound closure and use of surgical drains. In addition patient oxygenation and normothermia intra-operatively are also associated with SSI.

1.2.3.1. Surgical technique

One of the most important factors in determining post-operative infection rates, particularly SSI, is the competence of the individual surgeon (Mishriki, Law et al. 1990; Mishriki, Law et al. 1991). Best practice guidelines for SSI prevention also acknowledge the importance of surgical technique as a risk factor (Ayliffe 1991; Mangram, Horan et al. 1999).

1.2.3.2. Wound incision

The use of diathermy for routine skin incision and tissue dissection is gaining wider acceptance amongst surgeons (Chrysos, Athanasakis et al. 2005). Cutting diathermy has been shown to produce an incision which heals as well as one created with a scalpel, but with the added advantage of increased haemostasis and decreased operative time (Sebben 1988). A Greek study of 125 patients in 2005 prospectively examined diathermy (57 patients) and scalpel incisions (60 patients) in those undergoing tension-free inguinal hernioplasty (Chrysos, Athanasakis et al. 2005). Patients were assessed for post-operative SSI on the day of discharge, day of removal of staples, and one month post operatively. There were no infectious complications. However, this is a procedure for which the SSI rate is very low and a higher powered study with far greater numbers of patients would be required to show a difference in SSI rates.

A prospective randomized controlled trial comparing diathermy incision with scalpel incision across a range of different general surgical procedures randomized 369 patients to undergo either diathermy in 185 patients or scalpel incision in 184 patients (Shamim 2009). Post-operative SSI rates were recorded as well as incision time, blood loss, post-operative pain and duration of hospital stay. No statistically significant difference was observed between SSI rates for the two techniques. However diathermy was associated with reduced incision time, lower intra-operative blood loss, and reduced post-operative pain, all potentially proxy indicators for reduced SSI rates. Furthermore, maintaining careful haemostasis is recognized as best practice in decreasing SSI rates (Leaper, Burman-Roy et al. 2008).

Other studies of thoracotomy and gynaecology/oncology surgical procedures demonstrated no difference in SSI rates with diathermy (Stolz, Schutzner et al. 2004). In addition, a trial of 100 patients compared blood loss between diathermy and scalpel incision for elective midline laparotomy wounds (Kearns, Connolly et al. 2001). Parameters measured included SSI, as well as incision time, wound size, intra-operative blood loss and post-operative wound pain. Blood loss was significantly reduced in the diathermy group (0.8 vs. 1.7 ml/cm², p=0.002), and post-operative wound pain in the first 48 hours was also significantly reduced, although there was no statistical differences in SSI rates.

A study of 49 patients undergoing mastectomy noted less operative blood loss with diathermy compared with scalpel incisions (Miller, Paull et al. 1988) as did a recent neurosurgical trial, with blood loss during skin opening three to five times less, when diathermy was used (Sheikh 2004). Somewhat controversially then the most recent NICE guidelines in the UK recommend avoiding diathermy for skin incision (2008) despite the potential advantages of reduced incision time, reduced blood loss and less post-operative pain. Further studies are required to confirm that diathermy can assist in minimizing SSI rates.

1.2.3.3. Tissue handling

Handling tissue gently, minimizing devitalized tissue and foreign bodies, and eradicating dead space at the surgical site is recommended to avoid SSI (Mangram, Horan et al. 1999). Intra-operatively, forceps are used for the handling of tissue, suture and needles, but may damage tissue because of the tremendous concentration of force at the tips. While forceps are

a necessity, consideration should be given to the use of skin hooks or tacking sutures to minimize tissue damage (Jordan 1999).

It seems intuitive that the rough handling of tissue intra-operatively should lead to a higher rate of tissue necrosis which predisposes to infection. However, there are few studies in the literature confirming this. Attempts to quantify tissue handling intra-operatively in relation to SSI using a graded self assessment questionnaire, which does not detail specifics of surgical technique, have been made (Ford, Jones et al. 2005). The contribution of the different suture types to the overall improvement of surgical handling and technique were subjectively assessed, but without a clear definition of what the surgical technique entailed. In one such study, paediatric general surgeons were asked to grade the intra-operative handling of two different suture types, with surgical handling being graded from poor to excellent, the ease of suture passage through tissue, the security and smoothness of knot tying and the occurrence of suture fraying (Ford, Jones et al. 2005). In this study the coating of a vicryl suture with an antibacterial agent did not adversely affect its handling.

1.2.3.4. Wound closure

Surgical wounds or sites may heal by primary intention, delayed primary intention or secondary intention. A delay in wound closure of four to five days, if the wound is contaminated, increases the tensile strength of the wound with less likelihood of SSI development (Leaper DJ 1998). Recent recommendations quote a fall in SSI rate to 5% when leaving the wound open for four days to allow for treatment of the infection through regular

dressing changes and antibiotic therapy, before subsequent stitching of the wound to facilitate healing by primary intention (Gottrup 2005).

Where the potential risk of SSI is low, e.g. in elective inguinal hernia repair, primary closure has been routinely favoured, decreasing wound healing time and minimizing scar formation. Primary closure can be obtained by means of either continuous or interrupted sutures. A recent multicenter randomized trial of 625 patients undergoing laparotomy showed no significant difference in SSI rates between patients whose wounds were closed with continuous or interrupted sutures (Seiler, Bruckner et al. 2009). Previous smaller studies also investigated the effect of different closure techniques on SSI rates (Richards, Balch et al. 1983; Wissing, van Vroonhoven et al. 1987; Trimbos, Smit et al. 1992; Colombo, Maggioni et al. 1997) but none found a statistically significant difference in the SSI rate. However the use of continuous sutures is quicker (McNeil and Sugerman 1986; Trimbos, Smit et al. 1992; Sahlin, Ahlberg et al. 1993; Colombo, Maggioni et al. 1997), thus shortening operative duration, an independent risk factor for SSI (Campbell, Henderson et al. 2008).

Irrespective of the suture technique used to close wounds, individual suture types may have an impact on SSI rates. Sutures can be categorized into absorbable and non-absorbable. Absorbable sutures are broken down *in-vivo* by proteolytic enzymatic degradation, e.g. the previously widely used catgut, as well as polyglycolic acid (i.e. Vicryl, ©Ethicon Inc.), polydioxanone (PDS, ©Ethicon Inc.) and poliglecaprone (Monocryl, ©Ethicon Inc.). The interval to suture absorption varies depending on suture type from 10 days to eight weeks. Absorbable sutures are used in internal body tissues or for skin closure in patients for whom it would be potentially complicated to re-operate for suture removal.

Non-absorbable sutures are used for internal body tissues where a hostile environment, e.g. tissue with surrounding infection, precludes the use of absorbable sutures for skin closure. Examples include silk, polypropylene (i.e. Prolene, ©Ethicon Inc.) and nylon (i.e. Ethilon, ©Ethicon Inc.). While a number of publications have investigated different suture types used for wound closure and their impact on SSI rates, a recent meta-analysis found no significant difference in SSI rates with regard to the suture type used (van 't Riet, Steyerberg et al. 2002). Similarly, a number of studies have assessed absorbable versus non-absorbable sutures (Corman, Veidenheimer et al. 1981; Richards, Balch et al. 1983; Wissing, van Vroonhoven et al. 1987) as well as rapidly absorbable versus slowly absorbable sutures (Wissing, van Vroonhoven et al. 1987), but none have revealed a statistically significant advantage of using one over the other.

1.2.3.5. Surgical drains

The intra-operative placement of surgical drains and the implications for reducing SSI has been addressed (Mangram, Horan et al. 1999). It is believed that unnecessary drains provide a route for ascending infections, thus increasing the risk of intra-abdominal infection (Kawai, Tani et al. 2006). However, drains are often required to facilitate the removal of pus, other fluids and blood post-operatively, as their accumulation are a risk for post-operative infection. Several trials have shown that prophylactic drain placement in elective hepatectomy, colectomy and cholecystectomy have not decreased surgical complication rates (Fong, Brennan et al. 1996; Merad, Yahchouchi et al. 1998; Merad, Hay et al. 1999; Liu, Fan et al. 2004). As such drains should only be used when necessary and their prolonged use has

been shown to cause an increase in SSI rates(Hernandez, Ramos et al. 2005; Kawai, Tani et al. 2006). Therefore surgical drains should be removed as soon as possible.

It has been previously shown that bringing an abdominal drain out through the same skin incision as the initial surgical site or wound is associated with an increased risk of SSI (Fry 2003). Consequently, it is recommended that drains be placed through separate incisions and that closed suction drains be used preferentially over open drains (Fry 2003; 2008).

1.2.3.6. Maintenance of patient oxygen saturation

It has been reported that the decisive period for SSI development is during surgery and immediately post-operatively, therefore the physiological status of the patient at that time is essential (Gottrup 2000). The majority of SSIs develop in subcutaneous tissue, and oxygen delivery to tissues is an important factor for wound healing (Hunt, Zederfeldt et al. 1969). Maintaining intra-operative patient oxygenation would therefore logically assist in the prevention of SSI (Humphreys 2009). Recent studies support this assumption. A previous randomized controlled trial reported a 39% lower risk of SSI when 80% inspired oxygen is used rather than 30% (Belda, Aguilera et al. 2005). Best practice guidelines recommend giving patients sufficient oxygen during surgery to ensure that a haemoglobin saturation of more than 95% is maintained.

1.2.3.7. Maintenance of patient temperature

Best practice guidelines for prevention of SSI recommend that patients intra-operative temperature be maintained at a minimum of 36 degrees centigrade (Meeks, Lally et al. ; Guideline 2008). This guideline is based on a study by Kurtz et al wherein a significant decrease in SSI from 19% to 6% ($p=0.009$) was demonstrated in patients undergoing colorectal surgery whose temperature was maintained (Kurz, Sessler et al. 1996). A further study of patients undergoing breast, hernia and varicose vein surgeries also demonstrated a decreased SSI rate amongst patients who were warmed pre-operatively (Melling, Ali et al. 2001). Maintenance of patient normothermia is now considered standard peri-operative care in surgical patients.

1.2.3.8. Patient glucose control

Recent studies have identified peri-operative hyperglycaemia as a predictor of SSI (Serra-Aracil, Garcia-Domingo et al. 2011). It is recommended that glycaemic control is closely monitored in the acute phase of surgical patient care, from the time of operation until a minimum of 48 hours post-procedure (Rosenberger, Politano et al. 2011). However the routine administration of insulin to patients who do not have diabetes to optimise blood glucose postoperatively as a means of reducing the risk of surgical site infection is not recommended in recent guidelines (NICE 2008).

1.2.4. Post-operative risk factors

Post-operative risk factors include duration of antimicrobial prophylaxis as well as optimal maintenance of surgical site dressings.

1.2.4.1. Post operative duration of surgical prophylaxis

Strictly speaking, surgical prophylaxis should consist of one dose of antimicrobial agents or two if the procedure is prolonged as the purpose of this intervention is to prevent infection arising during surgery and not to treat established infection. Surgery can be classified as clean, clean-contaminated or contaminated. For clean procedures no prophylaxis is usually required although occasionally prophylaxis may be indicated if there is an increased risk of infection or if the patient is immunosuppressed. In clean-contaminated procedures, it is suggested that no more than one stat dose of prophylaxis is required for short procedures. However in many centers it is common practice to give 24 hours prophylaxis as is the case within our own institution. For contaminated procedures a treatment course of 5-7 days may be continued, although this is a treatment course rather than prophylaxis alone.

1.2.4.2. Maintenance of wound dressings post-operatively

The dressing should be clean, adherent where appropriate, and provide adequate wound coverage. This should involve low adherence, transparent polyurethane dressings which protect the wound, but also give the opportunity to check the surgical site for any signs of wound infection without having to disturb the dressing itself (Guideline 2008). Where transparent dressings are not available inspection of the surgical site should be postponed until 48 hours post operatively.

1.2.5. Factors associated with CRBSI

A number of modifiable risk factors exist to prevent CRBSI in patients with peripheral vascular catheters (PVC) and central venous catheters (CVC) *in-situ*.

1.2.5.1. Prompt removal of unnecessary PVCs and CVCs

Given that duration *in-situ* is a major risk factor in CRBSI it is vital that non-essential PVCs be promptly removed. Studies suggest that the incidence of both phlebitis and bacterial colonisation of the catheter tip increases when PVCs are left in place longer than 72 hours (O'Grady, Alexander et al. 2002). Where peripheral venous access remains necessary best practice guidelines suggest that in the absence of a dedicated intra-venous catheter monitoring team, the duration of cannulation should be limited to 72 hours or less where possible and therefore in such cases the PVC should be replaced and re-sited (Cercenado, Ena et al. 1990; Maki and Ringer 1991).

The duration of CVC has also been associated with an increased infection risk(2000) therefore if a CVC is no longer essential it should be removed promptly. However the routine replacement of CVCs which remain necessary and where there is no evidence of local or systemic sepsis is not indicated (SARI 2009).

1.2.5.2. Intravenous catheter dressings

Best practice guidelines relating to PVC care also stress the importance of clean and intact PVC dressings in the prevention of CRBSI (SARI 2009). It is recommended that the PVC should be stabilised with a sterile transparent semi-permeable dressing and sterile adhesive tape to prevent dislodgement. The ability to visualise the PVC site and surrounding tissues is important and therefore the PVC dressing should be transparent as well as intact and clean (SARI 2009).

With regard to CVCs, a dressing should be used to protect the insertion site. However, the dressing should be permeable to water vapour, as occlusive dressings trap moisture on the skin and can provide an ideal environment for the rapid growth of microorganisms (SARI 2009). The specific type of dressing is unimportant if it is transparent and semi-permeable (O'Grady, Alexander et al. 2002). Furthermore it is recommended that the CVC dressing be changed every seven days or sooner if the dressing is no longer intact or if moisture collects under the dressing (SARI 2009).

1.2.5.3. Risk factors associated with the insertion of CVCs

There are a number of factors associated with CVC insertion which if not optimally addressed can result in an increased CRBSI rate.

1.2.5.3.1. Choice of site and type of CVC

A recent study of over 2,000 medical and surgical intensive care unit patients analysed the incidence of CVC-related CRBSI and CVC-related local infection according to different placement sites (Lorente, Henry et al. 2005). In this study, CVC-related local infection incidence density was statistically higher for femoral than for jugular (15.83 versus 7.65, $p < 0.001$) and subclavian catheters (15.83 versus 1.57, $p < 0.001$), and higher for jugular than for subclavian access (7.65 versus 1.57, $p < 0.001$). CRBSI incidence density was also statistically higher for femoral than for jugular (8.34 versus 2.99, $p = 0.002$) and subclavian (8.34 versus 0.97, $p < 0.001$) access, and higher for jugular than for subclavian access (2.99

versus 0.97, $p = 0.005$). Therefore when minimizing infection the order for puncture is subclavian (first order), jugular (second order) and femoral vein (third order).

Patients should be assessed prior to CVC insertion as to the appropriate number of lumens that are likely to be required. If a multi-lumen CVC is used, one port should be identified and designated exclusively for TPN, if required (Ishizuka, Nagata et al. 2008; SARI 2009). In general it is best to utilise a catheter with the minimum number of lumens required, as this contributes to minimizing infection.

1.2.5.3.2. Method of CVC insertion

Hand hygiene prior to insertion as part of a full surgical scrub should be performed using an anti-microbial soap or an alcohol-based hand rub. Aseptic technique is essential during CVC insertion (O'Grady, Alexander et al. 2002). Correct sterile attire is also necessary including sterile gloves, gown, mask and cap (O'Grady, Alexander et al. 2002). Hair removal should be performed at the insertion site if necessary, and chlorhexidine 2% in 70% alcohol should be applied to the insertion site and allowed to dry before insertion. Appropriately sized drapes should be utilized in order to maintain an aseptic technique. After insertion, a dry semi-permeable dressing should be applied (O'Grady, Alexander et al. 2002).

1.2.6. Hand hygiene

Hand hygiene is the cornerstone of HCAI prevention. In 1846, Ignaz Semmelweis observed that women whose babies were delivered by physicians at the General Hospital of Vienna

consistently had a higher mortality rate than women whose babies were delivered by midwives (Semmelweis 1983). He postulated that the cause was “cadaverous particles” transmitted from the autopsy suite to the obstetrics ward via the hands of the physicians. In May 1847, he insisted that students and physicians clean their hands with a chlorine solution between each patient in the clinic. The maternal mortality rate in the First Clinic subsequently dropped dramatically (Semmelweis 1983). The hands of healthcare workers today may become transiently colonized with pathogenic flora (i.e. *Staphylococcus aureus*), gram-negative bacilli, or yeasts (Boyce and Pittet 2002)..

Current methods of maintaining hand hygiene involve hand washing, alcohol hand rubs, and surgical hand antiseptics protocols (Pittet, Mourouga et al. 1999). Several methods of increasing compliance with hand hygiene have been examined, including poster campaigns (Pittet, Hugonnet et al. 2000), in-service examinations with questionnaires (Mody, McNeil et al. 2003) and multimodal approaches involving lectures (Won, Chou et al. 2004). However compliance with hand hygiene remains poor (Thompson, Dwyer et al. 1997; Pittet, Mourouga et al. 1999).

1.3. Education of healthcare professionals

1.3.1. Previous education programmes and HCAI

1.3.1.1. Cost effectiveness

Some 20-30% of HCAI are considered to be preventable through an extensive infection prevention and control programme (Haley, Culver et al. 1985; Harbarth, Sax et al. 2003). For surgical patients, previous studies have demonstrated the potential for dramatic savings in

health care budgets. A recent prospective Spanish study identified an increased cost of \$97,433 U.S. dollars (USD) per patient with SSI. Ten percent of this cost was directly health related, with the remainder comprising of indirect social costs (Alfonso, Pereperez et al. 2007).

The potential for financial savings in CRBSI has also been previously demonstrated. In 2002 an educational initiative directed at nursing staff in an eighteen-bed surgical intensive care unit demonstrated cost savings secondary to the decreased infection rate of \$185,000-2,808,000 USD over 18 months (Coopersmith, Rebmann et al. 2002). Another ICU-based study estimated cost savings of \$1,945,922 USD over 12 months through an education programme focussing on enhanced CVC insertion and maintenance (Berenholtz, Pronovost et al. 2004). Another study recorded the dramatic costs saved through CRBSI prevention of \$103,600 - \$1,573,000 over 24 months (Warren, Zack et al. 2004).

There are other studies that have shown how hospital costs can be significantly reduced through education on infection prevention (Goetz, Kedzuf et al. 1999; Pittet, Mourouga et al. 1999; Sherertz, Ely et al. 2000; Coopersmith, Rebmann et al. 2002; Berenholtz, Pronovost et al. 2004; Topal, Conklin et al. 2005; Warren, Cosgrove et al. 2006). The costs of these educational interventions are small in comparison with the estimated savings (Pittet, Mourouga et al. 1999; Sherertz, Ely et al. 2000; Zack, Garrison et al. 2002; Warren, Zack et al. 2003). In these times of constrained financial resources, infection prevention and control measures become even more critical (Thorens, Kaelin et al. 1995; Fridkin, Pear et al. 1996; Archibald, Manning et al. 1997; Pittet, Mourouga et al. 1999).

National best-practice guidelines for prevention of HCAI apply to all individual health care practitioners (Pratt, Pellowe et al. 2007; Guideline 2008). Given the multidisciplinary nature of modern medicine, collective responsibility for HCAI prevention falls to different groups of health care workers. Many studies over the last 10 years have demonstrated success in educating nursing staff (Lange, Weiman et al. 1997; Goetz 1999) , critical care healthcare workers (Zack, Garrison et al. 2002; Warren, Zack et al. 2003; Rosenthal, Guzman et al. 2006) as well as medical students and junior doctors (Sherertz, Ely et al. 2000) in the prevention and control of infection. The success of these programmes is striking compared with the paucity of documented interventions in the surgical arena for surgeons specifically.

1.3.1.2. Nursing staff

As front line staff, adherence to infection prevention and control guidelines within the nursing profession is essential to decrease HCAI. There are a number of published studies promoting education programmes specifically for nurses. One such study focused on CVCs in the paediatric population. Here, protocols regarding the cleaning and dressing of the CVC insertion site, as well as CVC access, were promoted through posters and teaching sessions. As a result, infection rates among infants on surgical services fell from 15.46 to 6.67/1,000 catheter days (Lange, Weiman et al. 1997). A U.S. study provided nursing staff with unit-specific urinary tract infection (UTI) rates as an educational intervention combined with a video reviewing catheter care. In the post-intervention phase, a decrease in UTI rates resulted in an estimated cost saving of \$403,000 over 18 months (Goetz 1999). A recent ICU study displayed posters and storyboards highlighting best practice oral care for ventilated patients (Ross and Crumpler 2007). Nurses' competency in oral care was then formally assessed in

30-minute sessions with feedback provided. Through this education programme ventilator associated pneumonia (VAP) rates decreased by 50%.

1.3.1.3. Critical care healthcare workers

Much of the published education programmes on infection prevention and control have centred on critical care healthcare workers as the risk of infection in critical care areas is great and the consequences, in terms of clinical outcome and costs, are very significant. An Argentinean multi-center trial recently showed a significant decrease in the incidence of ventilator-associated pneumonia (VAP) through an eight month education programme for ICU personnel (Rosenthal, Guzman et al. 2006). The programme centered on one-hour educational sessions based on the 1997 CDC Nosocomial Pneumonia Prevention Guidelines. These sessions were offered to all physician, nursing, and ancillary staff and were focused on the epidemiology and pathogenesis of nosocomial pneumonia as well as hand hygiene and the proper handling of respiratory secretions and suction catheters. In addition, feedback of VAP rates was provided to ICU personnel on a monthly basis. Rates of VAP dropped from 51.28 episodes of VAP per 1000 mechanical ventilation days to 35.52 episodes. Given the cost of VAP (Dietrich, Demmler et al. 2002; Rosenthal, Guzman et al. 2005), these programmes are almost certainly very cost-effective.

The use of a self-study module to prevent CRBSI was pioneered in the US (Warren, Zack et al. 2003). The ten-page module was accompanied by a series of lectures and posters. Infection rates decreased from 4.9 to 2.1 cases per 1,000 catheter days. The effectiveness of a self-study module combined with posters, fact sheets and lectures has since been further

demonstrated in the ICU setting, with several studies showing significant decreases in CRBSI (Coopersmith, Rebmann et al. 2002; Warren, Zack et al. 2003; Coopersmith, Zack et al. 2004; Warren, Zack et al. 2004), VAP (Zack, Garrison et al. 2002; Babcock, Zack et al. 2004) and hand hygiene adherence (Mody, McNeil et al. 2003).

As technology improves, education programmes to change behaviour become more innovative. A web-based training module to decrease CRBSI between 1999 and 2002, also incorporating lectures and posters, was recently promoted effectively (Berenholtz, Pronovost et al. 2004). Surgical ICU physicians and nurses participated, with CRBSIs decreasing to zero from 11.3 per 1000 catheter days.

1.3.1.4. Medical students/junior doctors

A study from 2000 showed the effectiveness of a one-day teaching course in infection prevention and control (Sherertz, Ely et al. 2000). This study targeted medical students and doctors in their first postgraduate year. The course focused on the insertion and maintenance of CVCs and was in the form of a “hands-on” approach, where students/doctors rotated through a series of one-hour stations. As well as CVC insertion, these stations addressed arterial blood gas puncture, venepuncture to insert vascular lines, urinary catheter insertion, and lumbar puncture. The incidence of CRBSI was 4.9 cases per 1000 catheter-days beforehand compared with 2.1 cases in the post-intervention period (Sherertz, Ely et al. 2000).

1.3.1.5. Surgeons

There have been regional collaborations in surgery which have previously improved the overall quality of care with a fall in SSI rates (Fung-Kee-Fung, Watters et al. 2009). The importance of a large-scale safe care initiative in surgery has been recently demonstrated by the “Safe Surgery Saves Lives” proposal from the World Health Organisation (Haynes, Weiser et al. 2009). Through the introduction of a quality control checklist peri-operatively, SSI rates decreased significantly, from 6.2% to 3.4%.

A U.S. multicenter study involving 54 hospitals implementing best practice guidelines showed a decrease in SSI rates from 2.3% to 1.7% (Dellinger, Hausmann et al. 2005). Similarly 13 Dutch hospitals implemented antibiotic prophylaxis guidelines to decrease SSI rates from 5.4% to 4.6% (van Kasteren, Mannien et al. 2005). In this instance, guideline implementation was coupled with feedback and education on SSI rates to surgeons and other healthcare staff.

Given that it has been shown in one study that hospitals with a higher trainee-to-bed ratio also have an increased SSI incidence (Campbell, Henderson et al. 2008), it is surprising that a dedicated infection prevention and control programme emphasising the importance and relevance to surgical practice and incorporating the education of surgeons has yet to be established across the specialty. Consequently, there is much scope within surgery to improve patient care and reduce healthcare costs.

1.3.2. Novel educational approaches

The motivational factors influencing infection prevention and control behaviour are complex (Nicol, Watkins et al. 2009). Education in the domains of cognitive, psychomotor and affective learning need to be addressed to improve knowledge and infection prevention skills as well as to change attitude and behavior. As such, interventions need to be multifaceted to achieve success.

A recent study suggests that the local appointment of infection prevention and control coordinators, with the ongoing measurement of infection rates as well as feedback and accountability, contribute greatly to the success of such initiatives (Gagliardi, Eskicioglu et al. 2009). Education programmes are most effective when combined with adherence to strict practice protocols to maximize adherence (van Kasteren, Mannien et al. 2005; Vilar-Compte, Roldan-Marin et al. 2006; Ichikawa, Ishihara et al. 2007). Apart from education at a local level it is also important to stress the importance of HCAI as a quality and safety issue at organizational, regional and national level, as this is an under-taught area in our medical schools (O'Brien, Richards et al. 2009). When focusing on the educational aspect, it is difficult to determine which approach is the most effective. Previous studies have shown that the traditional approach of lecture-based education alone does not result in meaningful behavioral changes (Davis, Thomson et al. 1995). Rather it is thought that a blended learning approach, with particular focus on the small group format may be more effective. The positive effect of good mentor practices on students has been demonstrated in improving hand hygiene compliance (Snow, White et al. 2006). Similarly, direct supervision by an instructor providing positive and negative feedback in a hands-on learning environment is also effective (Sherertz, Ely et al. 2000).

New interventions involving web-based learning in combination with these established education formats are also proving successful in changing infection prevention and control behavior (Berenholtz, Pronovost et al. 2004).

The internet is an important source of healthcare information with the use of the world wide web expanding exponentially over the last decade (Lim, Phillips et al.). It has been estimated that in the United Kingdom alone, 18.3 of 26.1 million households (70%) had internet access in 2009, an increase of 4 million (28%) since 2006(28th August 2009; Gilliam, Speake et al. 2003). Against a societal backdrop that sees advances in information technology as commonplace, the rapid expansion of internet information now means that we have access to material that in the past would have needed a significant investment of time to both assemble and access (Mohanna 2007).

E-learning involves the use of internet technology to enhance knowledge, offering students control over learning content and allowing them to tailor their learning sequence individually (Ruiz, Mintzer et al. 2006). The last 5 years has seen e-learning become a high profile approach to educating medical students. It also facilitates continuing professional development (CPD) of healthcare professionals (Childs, Blenkinsopp et al. 2005; Daetwyler, Cohen et al. 2010). This has resulted in large investments in e-learning by third-level institutions for all student categories including medicine (Childs, Blenkinsopp et al. 2005).

1.4. The role of audit

Clinical audit is the systematic review and examination of current practice with reference to research based standards with a view to improving patient care. All healthcare systems are concerned with improving the quality of care. This is evident by the establishment of structures such as the UK NHS National Institute for Clinical Excellence (NICE), the Australian National Institute for Clinical Studies and by high profile reports (2001; Jamtvedt, Young et al. 2006). Internationally clinical audit is commonly used to both monitor and improve quality of care, and multiple studies have stressed the importance of the audit loop in achieving compliance with evidence based guidelines (Dawes 2001; McCleary and Raptis 2001; Gallagher, McLintock et al. 2003; Prasad, Sunderamoorthy et al. 2006; Taylor and Jones 2006). As such it forms the bridge between education of healthcare professionals and translation of learned theory into those healthcare professionals everyday practice. In essence, where education teaches professionals what *should* be done, clinical audit and re-audit ensures that what should be done *is* being done.

1.5. Aims

Our overall aim was to develop and evaluate a novel educational initiative targeting surgical trainees in order to improve knowledge and behaviour in the area of infection prevention in surgical patients. In a step-wise fashion our aims were to:

1. Design audit tools to evaluate practice amongst surgical teams
2. Review audit data in order to identify areas where deficiencies in patient care exist
3. Develop educational tools targeting these areas amongst surgeons
4. Encourage uptake of these educational tools by surgical trainees
5. Re-audit practice to determine whether the uptake of the educational initiative translated into improved clinical practice

Chapter Two

Materials and Methods

2.1. Overview

The study was carried out over a two year period from December 2008 until December 2010, and consisted of two separate parts.

The first study was carried out in Beaumont Hospital targeting surgical non-consultant hospital doctors (NCHD) and consultant surgeons in the Department of General Surgery. Beaumont Hospital is a 820-bed acute tertiary referral hospital with national centres for neurosurgery, renal transplantation and cochlear implantation. Audit tools were developed and piloted between December 2008 and June 2009. A detailed audit of surgical practice was carried out from July – December 2009.

Data from this audit was analysed and a web-based educational initiative developed to target deficiencies in practice which was implemented as part of a blended learning program over a six month period from January – June 2010. Following promotion of the educational initiative, a re-audit was carried out between July – September 2010 to determine the effectiveness of the educational initiative.

2.2. Development of audit tools

After an extensive literature review, as summarised in the introduction section of this thesis we highlighted a number of parameters to be assessed. These parameters were subdivided into pre-operative practice, intra-operative practice, post-operative practice, peripheral

venous catheter maintenance, central venous catheter insertion and central venous catheter maintenance.

In order to eliminate error in the transference of data from the data collection sheets to Excel format for statistical analysis, the Microsoft Excel populator program "Teleform©" was used.

2.2.1. Teleform© Software

Teleform© by Cardiff Software is a forms processing application based upon the principle of optical mark reading (OMR). Optical mark reading involves the use of a reader designed to read marks on paper forms. Applications using handprint recognition technology allow the transfer of data on paper forms to be converted into electronic format. Handprint recognition, sometimes called Intelligent Character Recognition (ICR), is a process where hand printed alpha-numeric characters are interpreted through software that compares the bitmapped image of the character to a large sampling (1000's) of actual hand printed characters and makes an intelligent decision as to what the character represents. The software then interprets each remaining character in the field to make a call as to what it represents. Teleform software consists of four different applications which when used in sequence allow for the design, scanning, verifying and exporting of data from paper form to Microsoft Excel for analysis. Advantages in using Teleform software include reduction in human data entry and human errors, and accelerated processing times. The three applications used are Teleform Designer©, Teleform Scanner©, and Teleform Verifier©.

Opening the Teleform Designer application allows the opportunity for the creation of a new "template", which is the data collection form or audit tool used in the studies outlined here.

The template is rendered unique through the allocation of a distinct number and barcode which appears at the top left hand corner of each printed copy of the template when completed and ready for use. (Figure 2.1)

Using the Teleform Designer application, specific fields are entered onto a form template and are named so as to equate to the Microsoft Excel field column name which they will ultimately generate. The data then entered into the field can be designated as letters, numbers or both (termed “alphanumeric”). Using the “Form Export” function, fields chosen to be exported are designated and a destination for output of the excel file is named. During this study all data sets were designed to be exported to a secure Beaumont Hospital server.

Figure 2.1: Example of data collection form

Peripheral Venous Catheter Form	
IV Line 1 Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of Insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine <input type="checkbox"/> Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/> Drawing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: _____ _____	
IV Line 2 Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of Insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine <input type="checkbox"/> Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/> Drawing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: _____ _____	
IV Line 3 Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of Insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine <input type="checkbox"/> Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/> Drawing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: _____ _____	
IV Line 4 Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of Insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine <input type="checkbox"/> Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/> Drawing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: _____ _____	
IV Line 5 Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of Insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine <input type="checkbox"/> Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/> Drawing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: _____ _____	

Once data collection was completed, the forms were then scanned using the “Teleform Scanner” application. When using this application, any number of the same form templates can be scanned automatically. When scanned, the forms are displayed as a digital photo image on the screen to allow checks for broad errors (i.e. scanning the wrong side of the form, or scanning a form upside down). The forms scanned are given a specific batch number and are queued for verification. When Teleform Verifier is then subsequently opened, it automatically retrieves all batches scanned and queued for verification. When verifying a batch of scanned forms each field on the form itself is displayed as a close-up photo image on the screen. Below this is a text box with the information in the field displayed as text. In the event that what the Teleform Scanner has identified being incorrect, this is corrected by the person verifying, who changes the information recorded in the text box to what it should be. When all of the completed fields in each form in a given batch have been verified and corrected where necessary, the batch information is then exported to the pre-designated secure server as determined in the design of the form using Teleform Designer. The exported file appears as a comma separated value (CSV) form, which can then be saved as Microsoft Excel. In this way audit data collected on data collection forms (or “bundles”) was converted into Excel format.

2.2.2. Data collection forms

Given that our parameters were subdivided into five sections, our forms were designed along this principle also. This led to the design of an intra-operative form which collected pre- and intra-operative data, as well as a post-operative form, peripheral venous catheter form, central venous catheter form and central venous catheter insertion form.

The intra-operative form was designed to collect the following data:

- Patient medical record number (MRN)
- Patient date of birth
- Name of surgical procedure
- Date of surgical procedure
- Start and end time of the procedure
- Speciality of surgical team carrying out the procedure
- Whether the procedure was directly witnessed by the auditing observer
- Whether hair removal was carried out using electric clippers or a razor
- Scrubbing technique of the surgical team
- Correct wearing of surgical attire, consisting of cap / gown / mask
- Whether the patient's temperature was maintained $>36^{\circ}\text{C}$ intra-operatively
- Whether the patients' oxygenation was maintained $>96\%$ intra-operatively
- What antibiotic was chosen as prophylaxis for the procedure
- What time the prophylactic antibiotic was administered

The post-operative form was designed to collect the following data:

- Patient MRN
- Date of surgery
- Surgical procedure performed
- Speciality of surgical team carrying out the procedure
- Whether the operation was classified as clean, contaminated or clean-contaminated

- Whether a clean dressing covered the surgical site
- Whether the surgical site dressing had been changed during the initial 48 hours after the procedure
- The duration of the prophylactic antibiotic / how many doses administered

The peripheral venous catheter form was designed to collect the following data:

- Whether the patients PVC was necessary
- If the PVC was unnecessary, why it had been originally sited.
- Whether the patient was aware of why the PVC had been sited
- Whether the PVC was sited during on-call hours (5pm – 9am) or between 9 am and 5pm
- The specialty of the surgical team caring for the patient
- Whether the patient was aware of their consultant's name
- Whether the PVC was *in-situ* for 72 hours or less
- Whether there was a clean intact dressing on the PVC
- Whether there was any evident of a PVC infection

The central venous catheter form was designed to collect the following data:

- Whether the CVC was necessary
- Whether the patient was aware of why the CVC had been sited
- Whether the dressing covering the CVC was intact and clean
- Whether the dressing covering the CVC had been changed in the preceding seven days

- Whether there was a designated port for TPN, where applicable
- The specialty of the surgical team caring for the patient

The central venous catheter insertion form was designed to collect the following data:

- Patient MRN
- Patient date of birth
- Date of CVC insertion
- Indication for CVC insertion
- Location of CVC insertion (i.e. theatre, ICU or Emergency Department)
- Whether the CVC insertion was an emergency or an elective procedure
- Specialty of doctor inserting the CVC (i.e. surgical or anaesthetic)
- Whether the doctor inserting the CVC was a consultant or an NCHD
- The venous site chosen for the CVC
- The number of lumens in the CVC chosen to be used
- Whether adequately sized drapes were used for the insertion procedure
- Whether chlorhexidine 2% was used and allowed to dry prior to insertion at the site chosen (Chlorhexidine 2% in 70% alcohol was not in the study hospital)
- Whether correct attire was worn (cap / mask / gown / sterile gloves)
- Whether hand hygiene was performed before CVC insertion
- Whether hand hygiene was performed after CVC insertion
- Whether the CVC once inserted was covered with a sterile dressing

2.2.3. Collection of initial audit data

The initial audit was carried out over a 5 month period from July 2009 until November 2009 in the Beaumont Hospital general surgical theatres and on the surgical wards. There are three general surgical theatres in Beaumont, theatres 3, 4 and 5. There are four general surgical wards, those being AB Cleary, St. Lukes, Hardwick and Jervis. The audit included ten surgical teams i.e., two upper gastrointestinal, three vascular, two colorectal and three breast and endocrine. All data was collected by a single observer (SMcH)

2.2.3.1. Intra-operative form data

Data was recorded directly onto the intra-operative form as discussed. In a proportion of surgical procedures it was not possible to directly observe the operative team. In these situations, data relating to scrubbing technique and surgical attire was not available. However, data relating to surgical prophylaxis choice and timing of administration, operation duration, patient intra-operative temperature and oxygenation, were available through retrospective chart review, once the patient was on the surgical wards.

2.2.3.2. Post-operative form data

Patients who underwent surgery in the preceding 48 hours were identified through the hospital theatre system, theatre logbooks, and follow up of patients identified through the intra-operative audit. These patients were then reviewed and questioned on the surgical wards with regard to their wound dressings. Prescription Kardexes were reviewed to determine the duration of surgical prophylaxis.

2.2.3.3. Peripheral venous catheter form data

Ward rounds specifically examining PVC were undertaken at least three times per week. Each patient with a PVC *in-situ* was included. The PVCs were directly viewed by the observer. Patient history, medical notes and the prescription Kardex were reviewed to determine the necessity of the PVC. In cases where it was not clear whether the PVC was necessary or not, a member of the surgical team was directly contacted and asked. The patients themselves were also interviewed to assess their perception of why the PVC had been sited. Each PVC was assessed independently. As such, patients with more than one PVC had each PVC individually assessed and were questioned regarding the necessity of each PVC. Patients were also interviewed about their awareness of their consultant's name. This section of the interview was per-patient rather than per-PVC. As such, patients were only assessed about their awareness of their consultant's name once, irrespective of the number of PVC they had *in-situ*. Patients who were unable to be interviewed (e.g. because of dementia or delirium secondary to sepsis) were excluded from the interview section of the PVC assessment.

2.2.3.4. Central venous catheter form data

During the ward rounds on surgical wards as described above, each patient with a CVC *in-situ* was also assessed. The CVCs were directly viewed by the observer. Patient history, medical notes and prescription Kardex were reviewed to determine necessity of CVC. In cases where it was not clear whether the CVC was necessary or unnecessary, a member of the surgical team were directly contacted and asked. The patients themselves were also

interviewed to assess their perception of why the CVC had been sited and whether they were aware of the name of their consultant.

2.2.3.5. Central venous catheter insertion form data

Where possible when a CVC was inserted, the procedure was observed in its entirety by a single observer and data was collected. The doctor inserting the CVC was interviewed to determine specialty and grade as well as the indication for a CVC.

2.3. The development of learning tools

After the literature review and based upon results of the initial audit, a blended learning approach was agreed and adopted. Although this was to include oral presentations and a poster campaign it was decided that the educational intervention would be centered on e-learning and web-based education. As such the concept of a website hosted on the World Wide Web was developed.

2.3.1. Website

The initial stage of website development is the planning of content. Hosting the e-learning platform on the World Wide Web not only allows for greater ease of access from participants but also allows a number of different e-learning modalities to be employed. As such we aimed to provide through the website:

- Information relating to best-practice guidelines, summarised for surgical trainees

- A search engine to provide instant recommendations for surgical prophylaxis choice and duration
- Interactive case presentations mirroring day-to-day clinical scenarios relating to infections in surgical patients
- Online audio-visual PowerPoint tutorials
- Streaming videos of best practice
- Podcasting (Figure 2)

With the importance of such a blended learning approach in mind, the design principles in our study educational initiative which incorporated e-learning focused on provision of a resource which facilitated four core objectives, namely accessibility, time-efficient learning, evidence-based resources, and problem based interactive formative assessment. In this manner we primarily utilized Miller's pyramid model of competence (Figure 2.2.). Guidelines and tutorials provided the basis for the recall of knowledge assessed in interactive clinical cases. These cases developed in complexity to ensure that the surgical trainee "knows how" in applying knowledge.

As such the domain name www.SurgInfection.com was purchased and hosted through the commercial company "In Motion Hosting" (www.inmotionhosting.com).

Figure 2.2.: Millers pyramid of competence

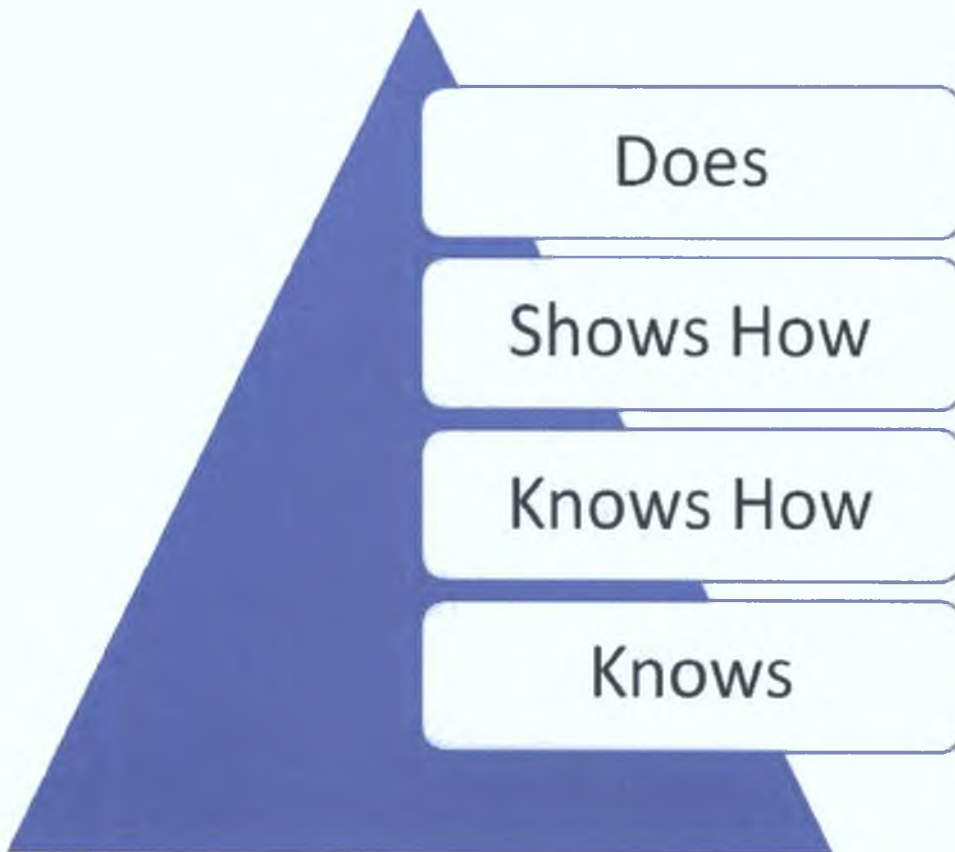
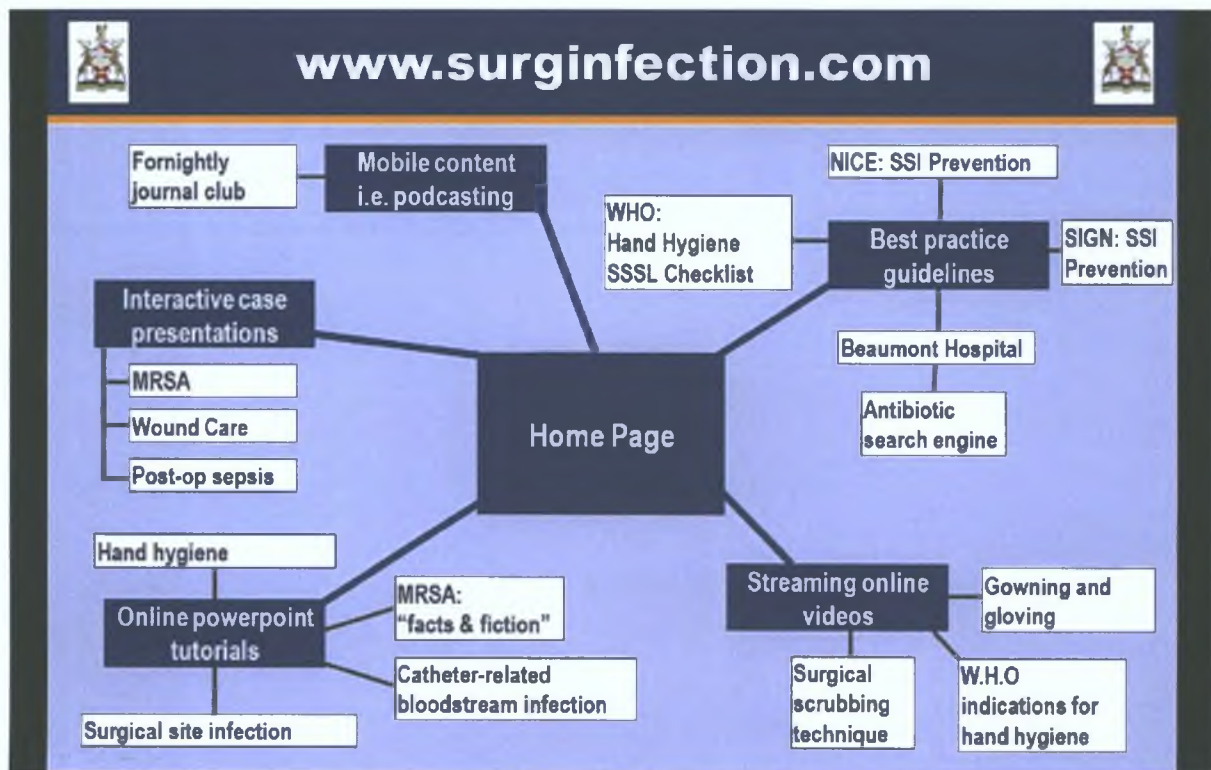


Figure 2.3: Overview of website content designed and presented during development of planned e-learning platforms.



MRSA: Methicillin resistant staphlococcus aureus

SSI: Surgical site infection

NICE: National institute of clinical excellence

WHO: World Health Organization

SIGN: Scottish Intercollegiate Guidelines Network

SSSL: Safe Surgery Saves Lives

2.3.1.1. Web language

The website was written using the web-based language Hypertext PreProcessor (PHP) which is a dynamic language embedded within Hypertext Markup Language (HTML), the static predominant language for web pages. Development of the website necessitated developing competence in their use.

2.3.1.1.1. HTML

HTML provides a means to create structured files by denoting semantics for text and graphics including titles, headings, paragraphs and lists. Internet browsers (i.e. Internet Explorer) read these files and display them as a webpage. In a basic sense, each entry to a HTML file is composed of three components – a start tag, content to be displayed and an end tag. The tags are keywords relating to commands for how the file is to be viewed in an internet browser and are enclosed in angular brackets.

All HTML files have two sections, a “head” and a “body”. The head relates to the title of the webpage, and the body to its content. Therefore as a simple example in order to create a webpage titled “SurgInfection” with content to include the words “The surgical infection prevention website” in bold font (where is the tag for bold font), we write:

```
<html>
<head>
<title>SurgInfection</title>
</head>
<body>
<b>The surgical infection prevention website</b>
</body>
</html>
```

2.3.1.1.2. PHP

PHP is deployed on all operating systems and platforms and does not require software installation to computers viewing PHP code on the internet. It is used to create dynamic webpage content. A dynamic webpage is not static because it changes with user interaction – i.e. different terms entered into a search engine return different results. As such creating a website in PHP provides a live user experience, where content viewed changes in response to different contexts.

PHP code is written within the PHP delimiters “<?php” and “?>”, which is then embedded within a HTML file. Although the PHP code written within the delimiters is not visible itself if that HTML file is viewed in an internet browser, it does define what is viewed. PHP code consists of a series of commands which when correctly employed direct the appropriate text or image to be viewed on screen. For instance the “echo” command in PHP allows for display of text on screen and can be deployed as a conditional response (i.e. IF this occurs, then “echo” that). As a straightforward example, in order to create a webpage titled “SurgInfection PHP”, with the text “This SurgInfection webpage is written in PHP” to appear when the page is opened in an internet browser, we write:

```
<html>
<head>
<title>SurgInfection PHP</title>
</head>
<body>
<?php
echo "This SurgInfection webpage is written in PHP"
?>
</body>
</html>
```

Web based language becomes more complex with increased functionality. An example of this increased complexity is included in the Appendix of this thesis.

2.3.1.2. Development of website sections

2.3.1.2.1. Guidelines

The Guidelines section of the website was created using the above web languages. In this section site users can choose to read web pages of content which summarize:

- Hand hygiene guidelines
- Peripheral and central venous catheter insertion and maintenance guidelines
- Guidelines on prophylactic antibiotics, choice and duration
- WHO safe surgery guidelines
- National institute for clinical excellence (NICE) guidelines relating to SSI prevention

Furthermore where available, copies of these documents were made available to site visitors for download. In addition we also created a Relevant Articles section, where recent peer-reviewed articles were highlighted and link to www.Pubmed.com from our site. SurgInfection users had the opportunity to subscribe to the Relevant articles RSS feed. Really Simple Syndication (RSS) feeds when subscribed to using a laptop or mobile device internet browser allow for automatic updates to that computer when new content (i.e. a relevant article link) is added to the RSS feed.

We also constructed an Antibiotic Search Engine to provide instant recommendations on surgical prophylaxis for site users for various procedures, i.e. cholecystectomy. (Figure 4)

Figure 2.4: Antibiotic search engine on SurgInfection website:

Surginfection

Antibiotic Search Engine

Enter operation name and click 'submit' to get surgical prophylaxis recommendations for the procedure

Enter Operation Name:

Antibiotics may need to be amended depending on patient's drug allergies and MRSA status

This search engine was constructed using PHP. A My Structure Query Language (MySQL) relational database stored on the SurgInfection.com server was populated with the Beaumont Hospital guidelines for antibiotic prophylaxis in terms of choice and duration of antibiotic for a range of surgical procedures encompassing general, orthopaedic and ear nose and throat surgery. The PHP code takes whatever is entered into the “Operation Name” search box, and searches the MySQL database for that operation. It then returns, or “echoes” the results found.

2.3.1.2.2. Tutorials

Camtasia Studio 4© software was used to create audio visual presentations. In order to create a series of tutorials we utilised this software to create a Flash© movies. We first created a series of presentations using Microsoft PowerPoint. Using Camtasia© we then added an audio commentary to a movie of the slides being scrolled through. On a Tutorials Homepage a series of links were made available on different subjects which consisted of:

- Peripheral venous catheter care
- Central venous catheter care
- Surgical site infection prevention
- MRSA and surgery
- Hand hygiene

Once the site user accesses the subject and opts to Start Presentation, the PowerPoint presentation begins, moving through the slides with audio commentary explaining each slide and discussing the points raised during the slide show. At any point the presentation can be

paused, rewound or stopped. The presentations are accessible 24 hours from any internet access point. Using this software we created a series of presentations not only stressing best practice guidelines but also making reference, where applicable, to findings in the initial audit carried out in Beaumont Hospital.

2.3.1.2.3. Clinical cases

Six interactive clinical cases were developed. The clinical scenarios chosen were:

- Abdominal collection after laparoscopic appendicectomy
- Hospital-acquired respiratory tract infection after cholecystectomy
- Central venous catheter infection
- MRSA osteomyelitis after an open femoral fracture
- *Clostridium difficile* colitis post partial colectomy

The clinical cases were constructed so as to lead the trainee through different stages of diagnosis, treatment and management of each patient journey while posing a series of questions to them at different stages. In order to see the answer, the trainee has to click on to the question, which links them to the answer and then back to the patient journey. This was done by constructing a large relational MySQL database on the remote SurgInfection server populated by both statements and images of the patient's journey, questions posed to the trainees, and answers to those questions. PHP code was then written to co-ordinate the trainees activities online with the remote MySQL database. A series of pre-determined pathways created when the MySQL database was calculated ensures that each question when

clicked on leads to the appropriate answer and back to the relevant stage of the patients journey.

2.3.1.2.4. Online videos

Videos of best practice from the Royal College of Surgeons in Edinburgh as well as Hand Hygiene Australia are hosted and available on the commercial site www.YouTube.com. Videos on this site are “streamed” to users' internet browser and do not need to be downloaded before playing. Videos of best practice on the prevention of infection relevant to surgical trainees were embedded from YouTube to the SurgInfection site. Those videos included:

- The five WHO indications for hand hygiene
- Gowning and gloving for surgery
- Correct surgical scrubbing technique

2.3.1.2.5. Podcasts

A podcast is a series of audio or video digital files released episodically and subscribed to using an RSS feed as detailed previously. In this section of the website we provided a journal club for surgical trainees in the field of surgical infection. This consisted of fortnightly reviews of recent published literature to determine articles relevant and interesting to surgical trainees in the field of surgical infection prevention.

Once an appropriate article was selected, it was reviewed by SMcH. An audio commentary, approximately 7-10 minutes in duration, was created using the freeware application Audacity©, a program designed for the creation of mp3 (audio) digital files. The audio commentary summarized the pertinent findings of the article as well as provided a brief critique on the strengths and weaknesses of the publication. The “SurgInfection Podcast” was submitted for acceptance into iTunes©. It was accepted in April 2010 becoming to our knowledge the first podcast by Irish doctors available worldwide through iTunes©. Trainees wishing to subscribe to the SurgInfection podcast can subscribe to it in iTunes, or through the SurgInfection website and receive fortnightly audio files of the journal club on surgical infection as mobile content. Furthermore the podcasts were also made available through a Flash music player embedded into the Podcasting section of the website. In this way trainees have the option of playing the podcasts directly on their laptop or desktop computer without needing to download or subscribe to a podcast feed, should they prefer.

2.3.1.2.6. Online survey

A Likert-scale based survey was constructed and hosted on the website. It was primarily aimed at healthcare professionals using the site, but available to be filled out by all visitors. Those electing to complete the survey were asked demographics such as gender, age, nationality and profession (i.e. branch of healthcare, or non healthcare). They were then asked to rate how beneficial they found the website, and how relevant they felt it to be on the prevention of infection in their patients. Ratings varied from Not Relevant, Minimally Relevant, Moderately Relevant, Very Relevant to Extremely Relevant. In addition, survey participants were asked to answer whether they felt the SurgInfection e-learning program should be continued, or expanded to include other surgical or non-surgical specialties.

Answers were selected through a drop down menu created using HTML. A PHP code populated a pre-created MySQL database on the SurgInfection server with the answers.

2.3.1.2.7. Other sections

The website also included an About Us section detailing the people closely involved with development and content of the website. A Contact Us section allowed for any comments or questions site users may have had.

2.3.2. Posters

In order to highlight deficiencies in the initial audit to be improved upon and also to promote use of the SurgInfection website a series of posters were designed. They were aimed at improving the care of surgical patients both in theatre and on surgical wards. Posters were placed in highly visible areas in the operating theatre, as well as in the surgeons scrub room. On surgical wards they were centered at nurses' stations and also along ward corridors. (Figure 5)

2.3.3. Lectures

A series of 15 minute lectures were delivered at weekly surgical grand rounds meetings as well as morbidity & mortality conferences held monthly in Beaumont Hospital. At these lectures surgical teams received feedback of audit results. Deficiencies in adherence to best practice were emphasized. Over a six month period from January to June 2010 there were six

such lectures. Lectures given in May and June also served to promote the SurgInfection website, where content was accessible from late April.

2.4. Evaluating learning tools

2.4.1. Re-audit of practice

To determine whether the blended learning program incorporating the SurgInfection website had been effective a re-audit was carried out. This audit was carried out in the same fashion as the initial 2009 audit by a single observer (SMcH).

2.4.2. Questionnaire for site users

Email notification of the website was sent to all basic surgical trainees in early August 2010. Surgical trainees visiting the website were invited to complete a questionnaire which was hosted on the SurgInfection website. Respondents were asked to answer a series of questions based on a Likert scale, assessing effectiveness and user friendliness of website as an educational intervention for surgical trainees.

Answers were again selected through a drop down menu created using HTML. A PHP code populated a pre-created MySQL database on the SurgInfection server with the answers.

Figure 2.5: One of the posters placed on surgical wards

**Even one unwashed hand can
have disastrous consequences**



Wash your hands **BEFORE and **AFTER** patient
contact to prevent infection**

www.surginfection.com

2.4.3. Quantitative assessment of website usage

Quantitative use of the website was performed using the commercial company “Hitslink©” (www.hitslink.com). Recorded variables included number of pages viewed, number of unique visitors, countries of visitors, time of day and duration of site access.

Descriptive statistics, exploratory, correlation and logistic regression analyses were performed at significance level $p < 0.05$ by the use of statistical software SPSS Ver.17. Specific tests included Student t test, Mann Whitney test and Cross tabulation with Chi squared analysis.

Chapter Three

Results and discussion of initial audit

3.1. Results of the initial audit

The initial five month audit to determine baseline clinical practice was undertaken between July and November 2009 assessing both SSI prevention parameters and CRBSI prevention parameters. The results are reported as collected through five previously described audit tools – intra-operative data results (comprising of pre and intra-operative parameters), post-operative data results, peripheral venous catheter maintenance results, central venous catheter insertion results and central venous catheter maintenance results.

3.1.1. Surgical site infection related parameters

3.1.1.1. Pre-operative parameters

Overall a total of 161 patient procedures were assessed. Seventy-two were directly witnessed while in the remaining 89 cases data were collected by post-operative review of the operative and anaesthetic notes. Of the 161 cases, 31 (19.3%) were laparoscopic and the remaining 130 (80.7%) open surgery. Clean procedures accounted for 83 (51.3%) cases, clean-contaminated procedures accounted for 69 (42.9%) with the remaining 9 (5.6%) procedures classified as being contaminated.

Sixty of the 161 procedures (37.3%) were upper gastrointestinal surgery. Of those 42 (70%) were directly witnessed and the operative notes for the remaining 18 (30%) reviewed. Vascular surgery procedures accounted for 46 (28.6%) procedures. Of the vascular procedures, 15 (32.6%) were directly witnessed and 31 (67.4%) reviewed post-operatively. The next most common specialty assessed intra-operatively was colorectal surgery (n=30, 18.6%) of which 9 (30%) were directly witnessed and 21 (70%) reviewed post operatively.

The remaining 25 (15.5%) procedures were breast and endocrine surgery. Of these 6 (24%) were witnessed and 76% (19) reviewed post-procedure.

3.1.1.1.1. Scrubbing technique

Of the 72 procedures witnessed, the scrubbing technique of the surgical technique was assessed in 65. Surgeons scrubbed using either Povidone-iodine or 2% chlorhexidine. Of these 65, 100% of surgical teams used an appropriate surgical scrubbing technique, in that surgeons scrubbed for at least three minutes and did not touch any unsterile surfaces whilst gowning and gloving.

3.1.1.1.2. Surgical attire

The surgical attire of surgical teams was directly observed. The correct wearing of the surgical cap was observed in 71 (98.6%). The surgical mask was worn correctly in 71 (98.6%) of cases, and the sterile gown was correctly worn in 68 (94.4%).

3.1.1.1.3. Timing of surgical prophylaxis

Overall surgical prophylaxis was assessed in 155 cases. Of these 147 (94.8%) documented the use of surgical prophylaxis, with eight (5.2%) patients not apparently receiving surgical prophylaxis. The most common antibiotic chosen was co-amoxiclav alone, accounting for 98 (60.9%) choices. The timing of surgical prophylaxis was available in 128 (79.5%) cases. Of these, prophylactic antibiotics were administered between 60 and 30 minutes prior to incision in only 7 (5.5%) cases. In 32 (25%) procedures surgical prophylaxis was administered less

than 30 minutes before the incision. In 50 (31.1%) cases antibiotics were given at incision, and in 39 (24.2%) cases surgical prophylaxis was administered after incision, the mean time being 2.75 minutes after incision. (Figure 3.1)

3.1.1.2. Intra-operative parameters

The procedure duration was available in 151 cases. The mean duration was 146.7 minutes (range 10-590 minutes).

3.1.1.2.1. Patient normothermia

Patient temperature was measured in 88/161 (54.6%) procedures. Of these, the patient temperature was maintained at greater than 36°C in 34 (38.6%).

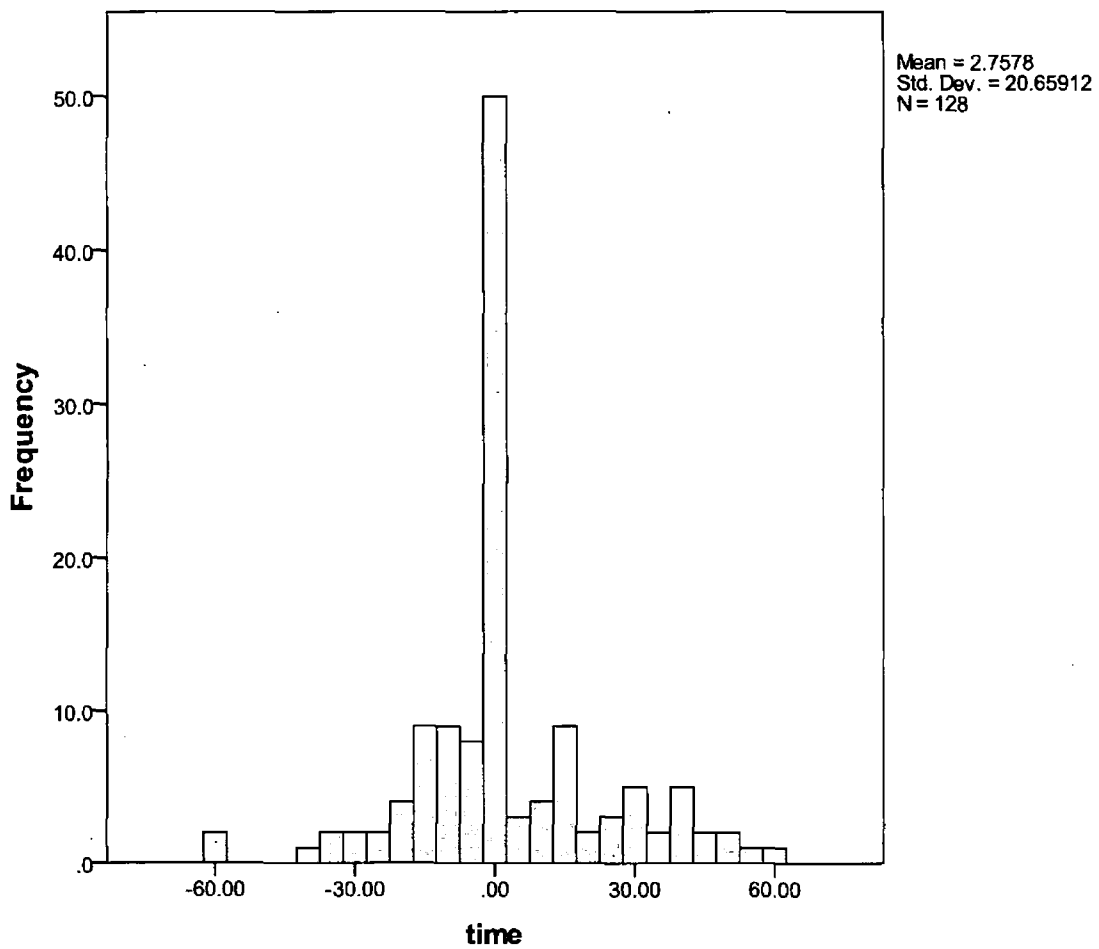
An increased operation duration was associated with a decreased maintenance of patient temperature >36°C ($p < 0.001$). Whether the procedure was laparoscopic or open was not a significant factor in maintaining normothermia ($p = 0.131$).

3.1.1.2.2. Patient oxygenation

Patient oxygenation on pulse oximetry was documented in 157/161 (97.5%) cases. Of these 153 (97.5%) were noted as being maintained >96% saturation. Patient oxygenation was not maintained in 4 (2.5%). The duration of the procedure ($p = 0.350$) or whether the procedure

was laparoscopic ($p=0.325$) or not were not associated with the maintenance of patient oxygenation.

Figure 3.1: Timing of surgical prophylaxis, from 60 minutes pre incision (-60), to 60 minutes after the start of surgery



3.1.1.3. Post-operative parameters

A total of 134 patients were reviewed on surgical wards post-operatively. The majority, 45 (33.6%), had undergone upper gastrointestinal surgery, with 40 (29.9%) under the care of the vascular service. Of the remainder, 25 (18.7%) patients were cared for by the breast surgery service, with colorectal surgery patients accounting for 17.9% (24). Of all these procedures, 31 (23.1%) underwent laparoscopic surgery and 103 (76.9%) open surgery. In total, 66 (49.3%) patients underwent clean surgery, with clean-contaminated surgery accounting for 46 (47.8%). Overall 4 (3%) patients underwent a contaminated procedure.

3.1.1.3.1. Duration of surgical prophylaxis

Overall 120 (89.6%) patients who were reviewed post-operatively had been prescribed surgical prophylaxis. Of patients undergoing clean surgery who were prescribed prophylaxis, 38 (69.1%) received a stat dose pre-operatively only. In 9 (16.4%) cases prophylaxis was prescribed for 24 hours. A total of 5 (9.1%) cases received 48 hours of prophylaxis, while three (5.5%) received greater than 48 hours prophylaxis. In patients who underwent clean-contaminated surgery, the majority (n=31, 50.8%) received prophylaxis for 24 hours duration. In total 15 (24.5%) received 48 hours of prophylaxis while only 12 (19.7%) received a stat dose pre-operatively only. In 3 (4.9%) cases prophylaxis was continued for more than 48 hours. In patients undergoing contaminated surgery, 3 (75%) received prophylaxis for more than 48 hours, with the remainder (n=1, 25%), receiving a stat dose in theatre only.

3.1.1.3.2. Surgical site dressings

In total 128 surgical site dressings were reviewed 24 hours post-operatively. Of those 98.4% (126) were noted to be clean and intact. At 48 hours post procedure 115 of these dressings were also reviewed. Of these 83.5% (96) were noted to have been *in-situ* without being tampered with in the initial 48 hours post procedure. In the remaining 14.2% (19), the dressings had been tampered with or changed within the initial 48 hours post procedure.

3.1.2. Catheter-related bloodstream infection prevention parameters

3.1.2.1. Peripheral venous catheter parameters

A total of 275 PVC were assessed over the five-month period; 220 (80%) were inserted during regular working hours (9am to 5pm), 51 (18.5%) during 'on-call' hours (5pm – 9am) and the timing of insertion could not be ascertained in four (1.5%) PVCs.

As the wards audited were predominantly surgical, 212 out of 275 (77%) PVCs were inserted by general surgical teams: 32 (12%) by the breast service, 38 (14%) by the colorectal service, 65 (24%) by the upper gastrointestinal service and 77 (28%) by the vascular service. Of the remaining 63 PVCs, 14 (5%) were inserted by the orthopaedic surgery service and the other 49 (18%) by medical teams, who had patients on surgical wards, due to a shortage of beds for acute medical patients.

Regarding PVC dressings, 240 (87%) were observed to be intact and clean. However, 35 (13%) dressings were either not clean or not intact. The majority of PVCs, 242 (88%) were

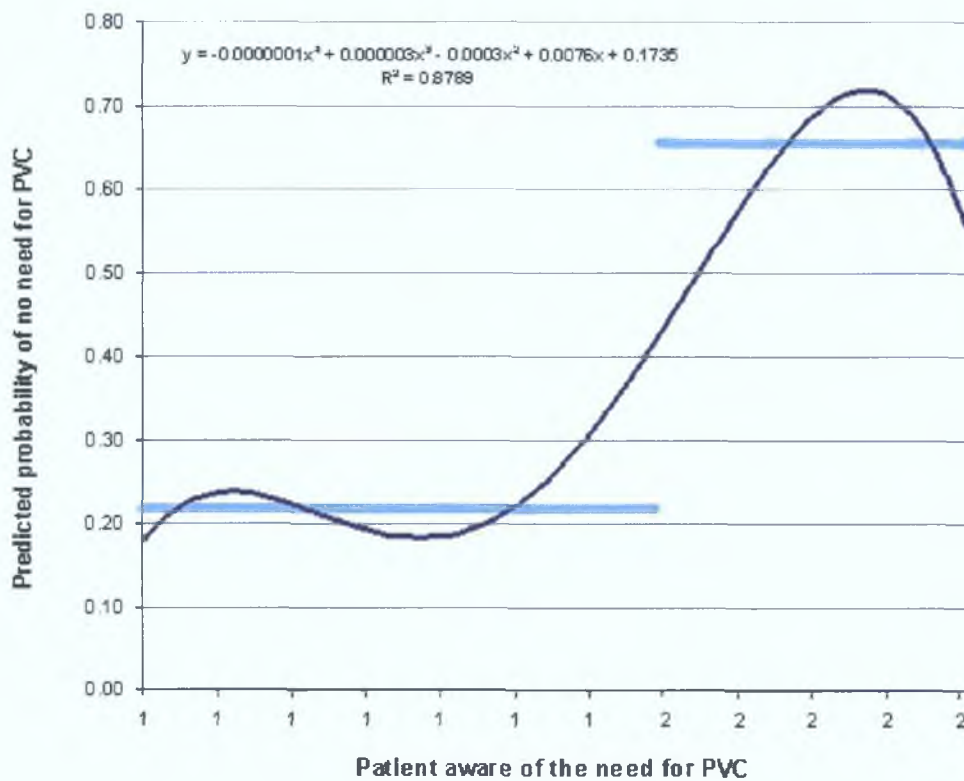
in-situ for 72 hours or less; 29 (11%) were *in-situ* for > 72 hours and in four PVCs the duration could not be ascertained.

Of the 275 cannulae assessed, 104 (37.8%) were no longer required at the time of assessment (“unnecessary”) while the remaining 171 (62.2%) were still considered necessary. There were three peripheral cannulae (1.1%) that were *in situ* for less than 72 hours but were observed to be associated with signs of phlebitis, and should have been removed. There were no PVC-related bloodstream infections recorded during the study period.

3.1.2.2.1. Patient awareness

Patients were questioned as to their understanding of the necessity of PVC in 178 cases; for 97 PVCs it was not possible to question the patient for a variety of reasons; i.e. the patient was not alert or well enough to respond. While 111 (62.4%), patients were aware of the reason for their PVC, 67 (37.6%) were not. The patient’s lack of awareness of the indication for their PVC was significantly associated with the patient having an unnecessary PVC *in-situ* ($p < 0.001$). Also, patients, who were unaware of the reason for their IV cannula were approximately seven times more likely (OR=6.935, 95%CI 3.523-13.650) to have an unnecessary peripheral IV cannula *in-situ*. (Figure 3.2)

Figure 3.2: Probability graph which represents the odds ratio associated with having an unnecessary PVC in-situ if the patient is unaware as to the indication for insertion originally. The line transecting the upper curve gives the ratio, demonstrating an almost seven-fold increase in the risk of patients having an unnecessary PVC in-situ if they were unaware as to why it was originally sited.



When further included in a logistic regression model (accuracy>73%, $p<0.001$), the predicted outcome probabilities were computed indicating clearly that if the patient was aware of the need for PVC (i.e., changing the state of the predictor from “No” to “Yes”) than a 2/3 reduction in the probability of having an unnecessary PVC might be achieved (from 66% to 22%). This relationship was best described by a non-linear (4-th order) function with the explained variance reaching the very high level of 90% ($R^2=0.88$). Patient awareness was not found to be significantly associated with whether the PVC dressing was intact and clean ($p=0.658$) or whether the PVC was *in-situ* for more than 72 hours ($p=0.645$).

As a sub-group analysis, 255 patients were asked whether they knew their consultant’s name. Of these, 213/255 (83.5%) did while 42 (16.5%) did not. Among the patients who did not know the name of their consultant, one third (14/42) had at least one unnecessary IV cannula *in situ*. There were no statistical associations between knowledge of consultants name and variables relating to PVC care as previously detailed.

3.1.2.2. Central venous catheter maintenance parameters

A total of 25 CVCs were reviewed on general surgical wards. Of these 20 (80%) were in upper gastrointestinal surgery patients, with two (8%) in patients under the breast service. Of the remainder, two (8%) were *in-situ* in medical patients and one (4%) *in-situ* in orthopaedic patients.

Central venous catheters were covered with a clean, intact transparent dressing in 20 (80%) cases. In 24 (96 %) cases the dressings had been changed within the last seven days as recommended. Seventeen patients (68%) were receiving total parenteral nutrition (TPN) via their CVC. In these patients, 16 (94%) were noted to have a designated port for TPN. Overall 24 (96%) CVCs were deemed necessary.

Of the 25 patients with CVCs *in situ*, 16 (64%) were aware of the necessity for the CVC i.e. why it had been originally sited. These patients were also questioned as to their knowledge of the name of the consultant who's care they were under, with 23 (92%) being aware. There was no significant association between necessity of CVC and patient awareness of necessity for CVC ($p=0.174$), or patient awareness of consultant's name ($p=0.763$).

3.1.2.3. Central venous catheter insertion parameters

A total of 17 CVC insertions were observed. All were performed in a theatre setting and were inserted to optimise peri-operative patient management. Of these, 16 (94.1%) were inserted for elective surgery; one (5.9%) was inserted in an emergency setting. Anaesthetists inserted the majority ($n=13$, 76.5%) with surgeons inserting the remaining four (23.5%). Doctors of registrar grade inserted 11 (64.7%) CVCs, with consultants inserting five (29.4%), and senior house officers inserting the remaining one (5.9%). The internal jugular vein was chosen as the insertion site in all cases.

3.1.2.3.1. Insertion site preparation

Chlorhexidine 2% was used as recommended in 9 (52.9%) cases, with chlorhexidine 0.5% used in 8 (47.1%). The skin antiseptic was allowed time to dry in 9 (52.9%) cases. Appropriately sized drapes were used in 100% of cases. After the CVC insertion a transparent sterile dressing (Tagaderm©) was applied to the insertion site in all cases.

3.1.2.3.2. Practice of doctor inserting central venous catheter

Appropriate hand hygiene was carried out before insertion in 16 (94.1%) cases that were observed. In all cases a surgical cap and sterile gloves were correctly worn. A face-mask was worn correctly in 14 (82.4%) cases, and a sterile gown worn appropriately in 9 (52.9%) procedures. In none of the procedures was hand hygiene carried out by the inserting doctor after the procedure.

3.2. Discussion

This audit highlighted a number of deficiencies in adherence to best practice guidelines for infection prevention in general surgical patients. In SSI prevention, improvement is necessary in the timing of surgical prophylaxis and the maintenance of patient normothermia. Post-operatively a significant number of surgical site dressings were tampered within the initial 48 hours post procedure, while surgical prophylaxis is frequently over-prescribed, when compared with local guidelines.

3.2.1. Surgical site infection prevention

Standard procedures for the prevention of SSI include adherence to best practice both in terms of appropriate prophylactic antibiotics, optimal intra-operative management and post-operative surgical site care (Mangram, Horan et al. 1999).

The rationale for administering surgical prophylaxis in the 60 minutes prior to incision as the standard for SSI prevention has been well articulated (Bratzler and Houck 2005; Forbes, Stephen et al. 2008). This ensures that a bactericidal concentration of the antimicrobial is established in serum and tissues by the time the skin is incised (Classen, Evans et al. 1992; Dellinger, Gross et al. 1994; Bratzler and Hunt 2006). In addition a recent Dutch multicentre audit demonstrated that a delay of more than two hours between prophylaxis administration and skin incision was associated with a 6.7-fold increase in SSI rates (van Kasteren, Kullberg et al. 2003). In fact the most appropriate time interval for surgical prophylaxis administration is between 59 and 30 minutes prior to incision as previously quoted in the literature (Kernodle D.S. 1995; Tourmousoglou, Yiannakopoulou et al. 2008). In 2008 a prospective observational study in Switzerland demonstrated a significant increase in the odds of SSI when prophylaxis was administered less than 30 minutes prior to incision rather than at 59-30 minutes pre-incision (Weber, Marti et al. 2008). This study focused on the use of cefuroxime only, but raises the issue as to whether the timing of surgical prophylaxis 59-30 minutes pre incision would allow a greater concentration of the antimicrobial to be present in tissue at incision. However, the guidelines in place in many countries as well as in our own institution contain a general recommendation to administer surgical prophylaxis within 60 minutes of the start of the operation.

Despite this, we have demonstrated that in our own hospital almost one quarter (24.2%) of surgical prophylaxis is administered after the initial incision rather than in the hour before incision. When focusing on the 59-30 minute pre-incision window, only 4.3% of surgical prophylaxis was administered at this point pre-operatively. Given the effectiveness of appropriately timed surgical prophylaxis in SSI prevention, this finding demonstrates a significant potential for improving patient care in our hospital through enhanced adherence to surgical prophylaxis timing guidelines.

The maintenance of patient normothermia is a further area where significant improvements are necessary in order to optimise patient care. A previous study of patients undergoing colorectal surgery demonstrated a significant decrease in SSI rates where the patient's body temperature was maintained above 36°C (Kurz, Sessler et al. 1996). In addition to increased SSI rates, complications attributed to peri-operative hypothermia include an increased incidence of myocardial ischaemia and coagulopathies. Furthermore peri-operative hypothermia is also associated with a prolonged hospital stay as well as increased hospital costs (Kurz, Sessler et al. 1996; Schmied, Kurz et al. 1996; Frank, Fleisher et al. 1997). Our audit revealed overall compliance of 38.6% with this guideline, a figure which decreased with increasing operative duration.

The use of Bair© huggers and fluid warmers have been shown to result in higher post-operative core temperatures and a lower incidence of peri-operative hypothermia (Andrzejowski, Turnbull et al.). A study of active warming on patients undergoing "clean" operations demonstrated a relative risk reduction of SSI of 57%. Furthermore previous interventions to improve practice with regard to patient warming have improved adherence to

peri-operative normothermia guidelines to as high as 97.6% (Forbes, Stephen et al. 2008). Increasing use of these preventative measures could decrease the numbers of patients with peri-operative hypothermia thus improving the quality of patient care by decreasing post-operative morbidity.

Best practice guidelines recommend that the surgical site be covered post-operatively with a clean intact dressing. In our audit compliance to this recommendation was over 98%. However nearly one sixth of surgical site dressings had been tampered with within the first 48 hours post procedure. There exists a paucity of published studies examining the effects of tampering with dressings in the initial post-operative period, but intuitively it is likely to contribute to an increased risk of SSI.

Of the dressings observed 83.5% were noted to have been *in-situ* without being tampered with in the initial 48 hours post procedure. In the remaining 14.2%, the dressings had been tampered with or changed within the initial 48 hours post procedure. One randomised study in 2001 demonstrated comparable SSI rates between patients whose wound dressings were or were not removed or not at 48 hours (Meylan and Tschantz 2001). However, this was a single centre study with only 50 patients in each group. Published best practice guidelines followed in our own institution recommend the maintenance where possible of the same post-operative surgical site dressing for the initial 48 hours post procedure.

In conclusion, particular deficiencies highlighted in our audit include the timing of surgical prophylaxis, patient hypothermia intra-operatively and sub-optimal maintenance of surgical

site dressings for the first 48 hours post procedure. Improvements in practice in these areas could improve the quality of patient care by decreasing surgical site infection rates.

3.2.2. Catheter-related bloodstream infection prevention

Our study has shown that a large proportion of PVCs were unnecessary (37.8%) and that many patients (37.6%) were unaware as to why they had a PVC.

Each year approximately 250,000 CVCs are inserted in the UK, and three million in the United States (Casey, Mermel et al. 2008; Hockenhull, Dwan et al. 2008). According to the results from the 2006 UK and Ireland HCAI Prevalence Survey, 66% of the patients in the Republic of Ireland had a PVC *in-situ* and 7.6% had a CVC (Fitzpatrick, McIlvenny et al. 2008). The majority of epidemiological studies on infection and vascular catheters are based on CVCs in intensive care units (ICU). The results from a nationwide US surveillance study indicated that 72% and 35% of patients with bloodstream infections had a CVC or PVC respectively *in-situ* (Wisplinghoff, Bischoff et al. 2004). The exact number of PVCs inserted outside ICUs is unknown, although it is assumed that the numbers are very large (Edgeworth 2009) and overall greater than those for CVCs in the ICU. This clearly indicates potential for the prevention of PVC-related hospital infections.

Peripheral IV cannulae that are no longer necessary for patient care should promptly be removed to minimise CRBSI. In this initial audit, we found that 37.8% of PVC were unnecessary, an issue that can be significantly improved in the future. Patients can also play an important role in the prevention of CRBSI. In our study, 37.6% of the patients were not

aware of the indication for their PVC. The importance of patient awareness with regards to HCAI prevention through hand hygiene compliance has been demonstrated previously (McGuckin, Waterman et al. 1999; McGuckin, Waterman et al. 2001; McGuckin, Taylor et al. 2004). Although some patients are reluctant to question their physician/surgeon about infection prevention and control practices (McGuckin, Taylor et al. 2004; Fitzpatrick, Pantle et al. 2009), educational programmes aimed at improving patient awareness and empowerment have increased hand hygiene compliance by up to 50% (McGuckin, Waterman et al. 2001). Previous programmes have educated patients to recognise signs of pain, swelling or redness at the cannula site which may indicate infection and to report their concern to their doctors (O'Grady, Alexander et al. 2002).

To the best of our knowledge, this is the first study to assess patient awareness in the area of CRBSI prevention. Individual patient awareness was a factor in whether a PVC was indicated, and patients who did not know the indication for their PVC were almost seven times more likely to have an unnecessary PVC *in-situ*, thus being at increased risk of CRBSI. This may well represent a deficiency in communication between healthcare professionals and patients given also the proportion of patients in our study who were unaware of their consultant's name.

With regard to infection prevention practice when inserting CVCs, we found that despite the majority being performed in an elective setting, a number of deficiencies were noted, in particular with regard to choice and application of site antisepsis, with nearly half of procedures advancing without allowing the chlorhexidine to dry. Similarly, the appropriate wearing of a surgical gown occurred in just over 50% with no doctor performing hand

hygiene after the procedure. Given that the insertion procedures observed were entirely carried out in a controlled theatre setting and that the vast majority were elective, this sub-optimal compliance may simply reflect a lack of awareness of best practice guidelines. We acknowledge however that in our audit we had relatively small numbers (n=17), and this is as a result of the unscheduled nature of CVC insertion making it difficult to observe.

In conclusion, this audit highlights a number of areas for potential improvement in CRBSI prevention, notably with regard to the numbers of unnecessary PVCs *in-situ* and adherence to infection prevention measures during CVC insertion. In combination with previously outlined potential areas for improvement in the prevention of SSI, these findings emphasise the need for the development of a targeted educational initiative in this area.

Chapter Four

An assessment of website use

4.1. Results

The www.SurgInfection.com website was launched on the 1st of July 2010. To promote its use at local level an announcement was placed on the Beaumont Hospital intranet homepage. Furthermore it was featured in the Beaumont Hospital fortnightly newsletter distributed throughout the hospital. During lectures and presentations feeding back audit data to surgical team's use of the website was encouraged. In addition posters placed on surgical wards directed viewers to the SurgInfection website for more detailed information.

At national and international level the website launch was announced on the Royal College of Surgeons in Ireland website homepage. An email announcing the website launch was circulated to all basic surgical trainees in Ireland. In addition the launch of the website was also featured in a number of medical national publications including the Irish Medical News and Epi-Insight, a monthly report on infectious disease in Ireland from the Health Protection Surveillance Centre (HPSC) an arm of the Health Service Executive (HSE). The website launch was also featured The Irish Times Health Supplement as well as the Irish Examiner, Irish Daily Mail and Irish Daily Mirror. (Figure 4.1)

As described in the Methods chapter, the website features five different learning platforms:

- A summary of best practice guidelines which were also made available
- PowerPoint tutorials produced as online 'flash' audiovisual movies
- Interactive clinical cases mirroring real-life scenarios
- An online repository of streaming videos demonstrating best practice.

Figure 4.1: Press cutting from the Irish Daily Mail announcing the launch of the education initiative

Doctors to get special lessons on scrubbing up

By **Petrina Vousden**
Health Editor

WASHING your hands isn't exactly brain surgery, but our future surgeons will have to undergo a special course to learn how to do it properly.

The Royal College of Surgeons of Ireland has introduced an online programme to help protect patients against hospital superbugs. It will test students' skills and knowledge of techniques and guidelines to ensure patient safety.

The 85 trainee surgeons who start their basic surgical training at the RCSI this month will be the first to use the new programme.

They will be able to access tutorials, videos and podcasts and reviews of all the latest published guidelines on surgical infection prevention.

Infections linked to healthcare affects about one in 15 patients admitted to our hospitals.

Proper hand washing by staff, patients and visitors are key measures in the fight against

these infections, but a 2009 study at University College Cork showed four out of ten Irish doctors and students were not washing their hands.

Stop Infections Now founder, Dr Teresa Graham, welcomed the programme.

She said: 'The more surgeons are made aware and educated about prevention and patient safety the better.'

'But my main worry is, no matter how many standards and guidelines are introduced there is no surveillance or strict enforcement of them.'

BRENDA POWER IS AWAY

- Fortnightly podcasts made available both on the SurgInfection website and on the 'iTunes ©' store for free download.

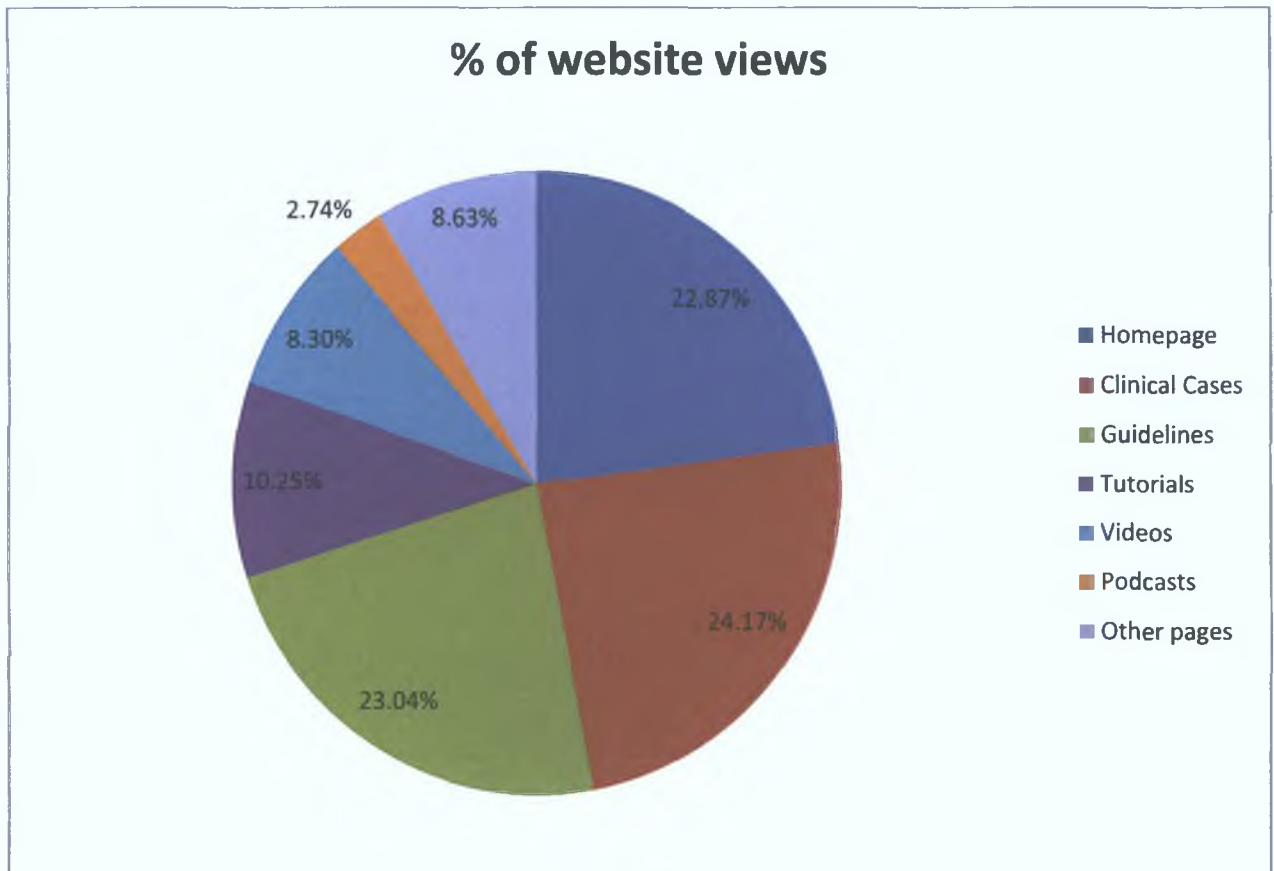
Use of the website was assessed quantitatively over 2-months from the launch of the educational initiative from 1st July 2010 – 1st Sept 2010, using the commercial company "Hitslink©" (www.hitslink.com).

4.1.1. Sections of website most accessed

Over the two month period the website received 9,878 views. The pages were viewed from 571 unique IP addresses. However, in a hospital setting multiple people will probably use the same computer at different times of the day. This may therefore represent a gross underestimation of the numbers of different people visiting the website.

The most commonly viewed single page was the website homepage, accounting for 2,254 (22.87%) views. With regard to the uptake of the different learning platforms, the interactive clinical cases web pages were most commonly accessed, accounting for 2,284 page views (24.17%). The guidelines sections were viewed 2,272 (23.04%) times. The PowerPoint tutorials were accessed 1,011 (10.25%) times. The streamed videos of best practice were viewed 819 (8.3%) times and the podcasting section was viewed 270 (2.74%) times (Figure 4.2). However, the podcasts could also be accessed through iTunes©, and this navigation pathway was not measured in our assessment. Other web viewings were made up of navigation through the "contact us" and "about us" sections as well as access to our online survey.

Figure 4.2: Pie-chart detailing access statistics of different sections of the website



4.1.2. Countries of visitors

Site visitors from Ireland accounted for 8,677 (87.84%) pages viewed. Of Irish website users during the study period, 30.99% visited the site multiple times. Visitors from the United States viewed the website 314 (3.17%) times. This was followed in frequency by viewings from the United Kingdom (n=217, 2.19%), Hong Kong (n=95, 0.96%) and Kenya (n=77, 0.77%).

4.1.3. Online survey

Visitors to the SurgInfection website were invited to participate in a “30 second survey” assessing the effectiveness and ease of use of the website as a learning tool for surgical trainees. A total of 61 visitors responded of whom 96.7% were healthcare professionals; 38 respondents detailed their exact profession, with surgical doctors accounting for 37.7% (n=23). Non-surgical hospital doctors accounted for 11.5% (7), allied health professionals 9.8% (6) and general practitioners 3.3% (2). In total 68.9% (42) were male and 31.1% (19) female. The majority of survey respondents (80.3%, n=49) were Irish.

4.1.3.1. Effectiveness of website

Of those surveyed, 78.7% (n=48) found the website “extremely” or “very” beneficial. A total of 9.8% (n=6) found it moderately beneficial, with only 11.5% (n=7) finding it of minimal or no benefit. Overall, 91.8% (n=56) found the site to be “extremely” or “very” relevant, with 4.9% (n=3) finding it moderately relevant and only 3.3% (n=2) finding it minimally relevant (Table 4.1). No survey respondents found the website content “not relevant” to the continuing education of surgical trainees. When questioned as to whether or not the online repository

programme should be continued beyond the study period, 100% (n=61) felt that it should be continued, and 98.4% (n=60) felt that it should be expanded beyond general surgery to include other surgical and non-surgical hospital specialties.

4.1.3.2. Ease of use

Of those surveyed 88.5% (n=54) rated the online programme “extremely” user -friendly. Of the remaining respondents, 6.6% (n=4) found the interface “very” user-friendly, with 4.9% (n=3) finding the interface moderately easy to use. No site users found the interface minimally user-friendly or not user-friendly (Table 4.1). There were no statistically significant associations between perceived ease of use and nationality ($p=0.347$), gender ($p=0.695$) or profession ($p=0.165$).

4.2. Discussion

There has been an expansion of internet information over the last decade which now affords access to material that in the past would have needed a significant investment of time to both assemble and access (Mohanna 2007). Through e-learning, educators can offer students and health professionals in continuing education control over learning content allowing them to individually tailor their learning (Ruiz, Mintzer et al. 2006).

Table 4.1: Table demonstrating effectiveness and ease of use of website as per the survey respondents

	Not at all	Minimally	Moderately	Very	Extremely
Beneficial (%)	8.2 (5)	3.3 (2)	9.8 (6)	3.3 (2)	75.4 (46)
Relevant (%)	0 (0)	3.3 (2)	4.9 (3)	6.6 (4)	85.2 (52)
User-friendly (%)	0 (0)	0 (0)	4.9 (3)	6.6 (4)	88.5 (54)

The last five years has seen e-learning become a high profile approach to facilitating continuing education of healthcare professionals(Childs, Blenkinsopp et al. 2005).

4.2.1. Quantitative use of the SurgInfection website

Our study details the development of a blended learning educational initiative incorporating traditional teaching tools such as lectures and posters with a novel e-learning program centered on a website providing a variety of learning platforms. We report high levels of website use particularly in the use of online interactive clinical cases and the provision of information through summarized guidelines.

The design principles in our study educational initiative which incorporated e-learning focused on the provision of a resource which facilitated four core objectives, namely accessibility, time-efficient learning, evidence-based resources, and problem based interactive formative assessment.

In this manner we primarily utilized Miller's pyramid model of competence. Guidelines and tutorials provided the basis for the recall of knowledge assessed in interactive clinical cases. These cases developed in complexity to ensure that the surgical trainee knows how to apply knowledge. Indeed it would appear that interactive virtual cases available which mirror real-life clinical scenarios are a more attractive learning tool as seen by the comparatively high number of hits compared other learning platforms. Through the design principles of our website these cases allow the trainee to apply the knowledge gained in the guidelines section of the website, which was also frequently accessed.

Varying degrees of effectiveness of the e-learning approach have been described, and previous studies have shown that internet formats are equivalent to non-internet formats in effecting changes in knowledge, skills and behaviour (Cook, Levinson et al. 2008). Furthermore, the hosting of an e-learning programme on the world wide web and combining it with mobile content delivery modules such as podcasts, ensures ease of access to important information for surgical trainees from anywhere in the world. This is borne out in our quantitative assessment of use, with over one fifth of site users resident outside of Ireland. In addition, 24 hour availability also allows for the integration of surgical infection prevention teaching in to the busy lives of surgical trainees. Previously, such learning was less structured, consisting of informal “on the job” learning, self driven learning or didactic sessions provided by other healthcare professionals. The development of a programme largely by surgeons for surgeons can assist in changing practice and culture. However, this programme is also available to other healthcare staff, thus integrating the education and practice of all professionals in the prevention and control of infection.

A limitation in our quantitative assessment of website uptake is that we cannot exactly determine the number of people accessing the website, only the number of times the different parts of the website are viewed. Furthermore accesses to the “SurgInfection Podcasts” through the iTunes© store navigation pathway could not be analysed, making it difficult to assess the uptake of our podcasts as a learning tool.

4.2.2. Cost-effectiveness

Many studies have shown how hospital costs can be significantly reduced with education on infection education (Coopersmith, Rebmann et al. 2002; Berenholtz, Pronovost et al. 2004; Alfonso, Pereperez et al. 2007). In terms of cost effectiveness, the cost of domain name purchase and online hosting of the website is €100 per annum. In contrast, the daily cost of a single catheter related blood stream infection in a surgical patient has been estimated at \$12-20,000 (Kilgore and Brossette 2008).

4.2.3. Online Survey

As well as demonstrating levels of use of our online educational programme we also surveyed perceived effectiveness and usability of the website among site visitors. The majority of respondents found it beneficial and relevant, with over 90% of those surveyed rating the information available as 'extremely' or 'very' relevant. When we consider that the majority of respondents were surgical doctors, this demonstrates a further benefit of the targeted model, aimed at specific deficiencies noted in surgeon's practice through the initial audit.

A recent systematic review reported a number of factors which influence student use of e-learning programmes (Wong, Greenhalgh et al.), claiming that students were more likely to engage in the programme if it was easy to use technically. Our survey indicates that the majority (88.5%) of students found our online repository easy to use, and this is reflected in our quantitative data which demonstrates high levels of website access over the study period. Aside from the quality and quantity of information available through an online learning programme, the importance of a user-friendly interface is again demonstrated in the survey

section of our study, with the vast majority rating the website as both beneficial and relevant, an objective which is only achievable when website visitors perceive an easy-to-use interface.

In conclusion, high levels of use combined with positive survey results indicate that the SurgInfection online e-learning platform is beneficial, relevant and easy to use. Use of the guidelines section to improve base knowledge combined with interactive online clinical cases to self assess this knowledge has proven the most effective learning method for our trainees. Assessment of the translation of this improvement in terms of knowledge and behaviour into better clinical practice can only be assessed through re-audit of clinical practice after implementation of educational intervention.

Chapter Five

Results and discussion of repeat audit

5.1. Results

The repeat audit was carried out following the launch of the education initiative. It was undertaken by a single observer (SMcH) in Beaumont Hospital from July until September 2010. The audit tools used to collect data were the same as utilised in the initial audit, and the results reported as described in the initial audit results in Chapter Three. Statistical parametric and non-parametric tests including Chi-squared analysis were used to determine whether there were significant improvements in practice between the results of the initial audit in 2009 and the re-audit in 2010. The statistical software SPSS v17 was used, with $p < 0.05$ considered significant. Where there were statistical differences between the pre- and post-intervention audits, these are stated. Otherwise there were no statistical differences between both periods.

5.1.1. Surgical site infection related parameters.

5.1.1.1. Pre-operative parameters

Over the three month repeat audit period there were 199 surgical procedures assessed. Of these, 60 (30.2%) were directly witnessed and 139 (69.8%) assessed through post-operative review of the operative and anaesthetic notes. Of the 199 procedures 120 (60.3%) were classified as clean, with 72 (36.2%) classified as clean-contaminated. The remaining seven (3.5%) were contaminated procedures.

Of these 199 procedures, 67 (33.7%) were breast surgery patients and 60 (30.2%) were under the care of the vascular surgery team. Of the remaining procedures, 39 (19.6%) were colorectal surgery and 33 (16.6%) upper gastrointestinal surgery. In total 60 (30.2%)

procedures were directly witnessed, and the medical notes of 139 (69.8%) reviewed immediately post-operatively. Of the breast surgery procedures, 14 (23.3%) were directly witnessed, as were 21 (31.3%) vascular surgery procedures. Of the colorectal procedures eight (20.5%) were witnessed, with 16 (48.5%) of upper gastrointestinal procedures also witnessed.

5.1.1.1.1. Scrubbing technique

Of the 60 procedures directly witnessed, the scrubbing technique of the operating team was observed in 45 (75%). Pre-operative scrubbing compliance with best practice was again at 100%, maintaining the same standard as seen in the initial 2009 audit.

5.1.1.1.2. Surgical attire

Surgical attire was observed in 59 procedures. The surgical cap, mask and gown were all worn correctly (100%). This was an improvement from the initial audit, where the surgical cap was worn correctly in 98.6% of cases, the mask in 94.4% of cases and gown in 98.6% of cases. However on cross-tabulation with Chi-squared analysis this was not found to be statistically significant ($p=0.364$, $p=0.364$ and $p=0.066$ respectively).

5.1.1.1.3. Timing of surgical prophylaxis

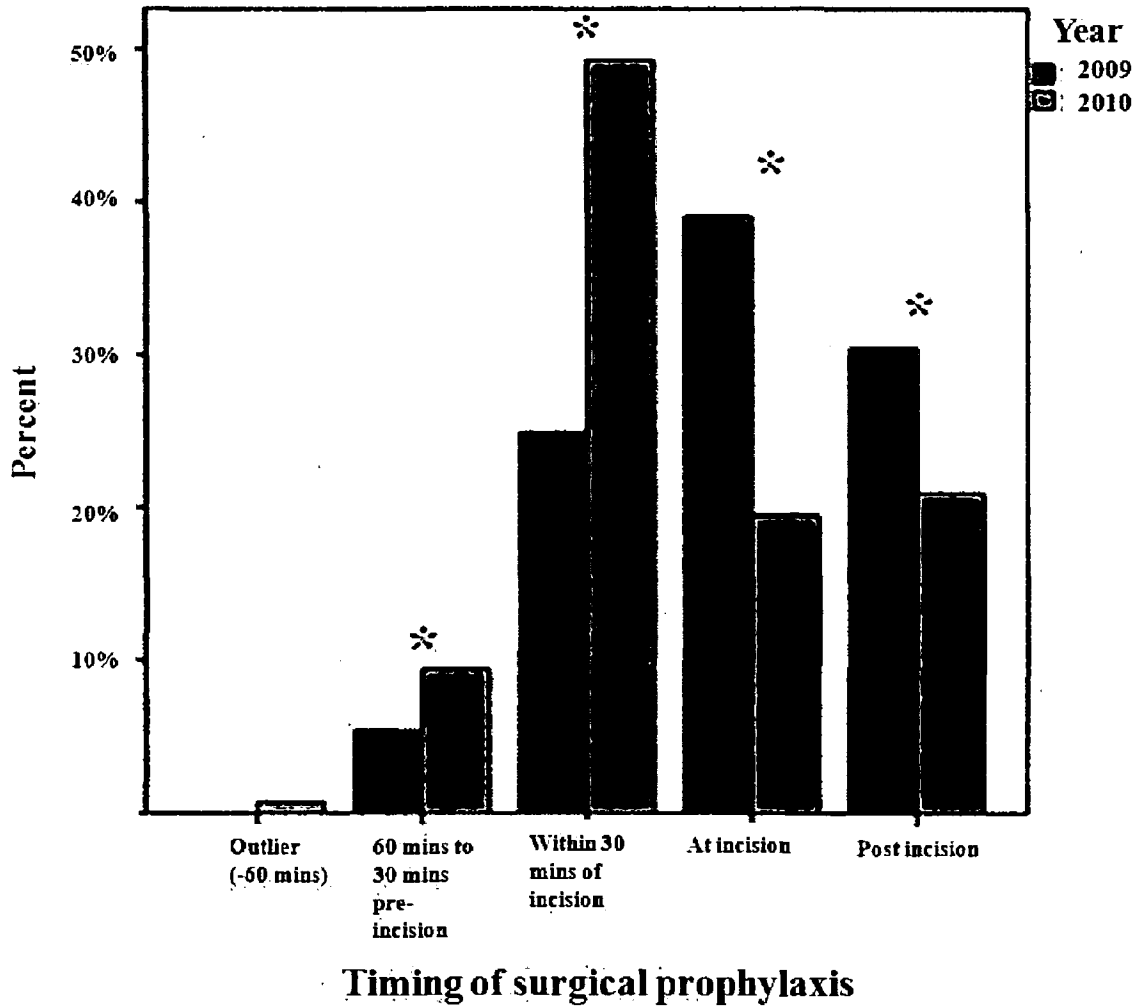
Surgical prophylaxis was used in 188 (94.5%) of cases. Of these 188 the timing of administration was available in 138 (73.4%). As in 2009, the most commonly chosen prophylaxis was intravenous co-amoxiclav alone, accounting for 145 (72.9%) instances of

prophylaxis administration. Administration between 60 and 30 minutes pre-incision occurred in 13 (9.4%) of cases. Administration within 30 minutes of incision occurred in 68 (49.3%) of cases, with 27 (19.6%) receiving antibiotics at the time of incision. Of the remaining procedures, 29 (21%) received antibiotics after incision with a further one case (0.7%) receiving prophylactic antibiotics 80 minutes before incision.

When compared with data from the initial audit through cross tabulation with Chi-squared analysis, these data represent a statistically significant improvement in the timing of prophylaxis (Figure 5.1). Although only a small increase was seen in the numbers of patients receiving prophylaxis in the optimal 60 to 30 minutes pre-incision (9.4% vs. 5.5%), there was a considerable increase in patients receiving antibiotics within 30 minutes of incision (49.3% vs. 25%). As a result, the percentage of cases where prophylaxis was inappropriately administered at the time of incision, or post incision decreased significantly ($p < 0.001$).

The mean time of administration was 6.2 minutes prior to incision, with a range of 80 minutes before incision to 70 minutes after incision and a standard deviation of 22.37mins. This represents a statistically significant improvement in the mean time of administration of 3.45 minutes ($p = 0.001$ using related-samples Wilcoxin signed ranks test) compared with the timing of administration in 2009 before the intervention. Furthermore it shifts the mean time of administration from post-incision to within 30 minutes pre-incision which is the recommended national guideline.

Figure 5.1: Clustered bar chart depicting significant improvement in the timing of surgical prophylaxis from 2009 to 2010 ($p < 0.001$).



* = statistical significance

5.1.1.2. Intra-operative parameters

With regard to the duration of procedure, this information was available in 175 (87.9%) of cases. The mean duration of procedure was 107 minutes (range 15-322 minutes).

5.1.1.2.1. Patient normothermia

Documentation of patient temperature was present in 89 (44.7%) cases. Of these, patient normothermia was maintained intra-operatively in 41 (46.1%). Those who had laparoscopic surgery were more likely to have their body temperature maintained $>36^{\circ}\text{C}$ ($n= 6/19, 68.4\%$) compared with open surgery ($n=28/70, 40\%$) ($p=0.028$).

Although a comparatively lower percentage (38.6%) of cases maintained patient normothermia in the 2009 audit, the improvement of 7.5% was not found to be statistically significant ($p=0.104$).

5.1.1.2.2. Patient oxygenation

Pulse oximetry was documented in 197 of 199 cases (98.9%). Of these, patient oxygenation was maintained at greater than 96% in 190 (95.5%) cases. This decrease of 2% compared with the results of 2009 was not significant ($p=0.588$).

5.1.1.3. Post-operative parameters

5.1.1.3.1. Duration of surgical prophylaxis

A total of 106 patients were reviewed post-operatively on surgical wards. Of this cohort of patients, 38 (35.8%) were vascular surgery patients, with upper gastrointestinal surgery patients making up the next largest sub-group with 29 (27.4%) patients. The remainder consisted of 22 colorectal surgery patients (20.8%) and 17 breast surgery patients (16%). Overall 22 (20.8%) had undergone a laparoscopic procedure, with 84 (79.2%) undergoing open surgery. Of the 106 patients reviewed post-operatively, surgical prophylaxis had been prescribed in 101 (95.3%) cases. Again, co-amoxiclav alone was the most commonly prescribed prophylactic agent, being prescribed in 86 (85.1%) cases where surgical prophylaxis was prescribed.

Of the 47 (46.5%) cases undergoing clean surgery, the majority received a stat dose only as prophylaxis (n=36, 76.6%), with five cases (10.6%) receiving a 24 hour course. Interestingly in six (12.8%) cases, prophylaxis was continued for more than 48 hours. With regard to the 46 (45.5%) cases undergoing clean-contaminated surgery, the majority in this subgroup received 24 hours duration of prophylaxis (n=29, 63%). Of the remainder, 13 (28.3%) received a stat dose only, with 3 (6.5%) receiving 48 hours of prophylaxis and only one case (2.2%) receiving prophylaxis for more than 48 hours. Only eight patients of the 106 underwent a contaminated surgical procedure, all of whom received prophylaxis for more than 48 hours. As was the case in 2009, these results achieved statistical significance, with those undergoing clean surgery more likely to receive a stat dose only, those undergoing clean-contaminated surgery likely to receive 24 hours prophylaxis, and those undergoing contaminated surgery more likely to have their antibiotic prophylaxis prolonged for longer than 24 hours ($p < 0.001$). However there were no statistically significant improvements in the duration of prophylaxis noted between 2009 and 2010.

5.1.1.3.2. Surgical site dressings

The surgical site dressing was reviewed in all 106 post-operative patients. In all cases, the surgical site was noted to be intact and clean. This was an improvement from 98.4% in 2009, however, this improvement was not found to be statistically significant ($p=0.196$).

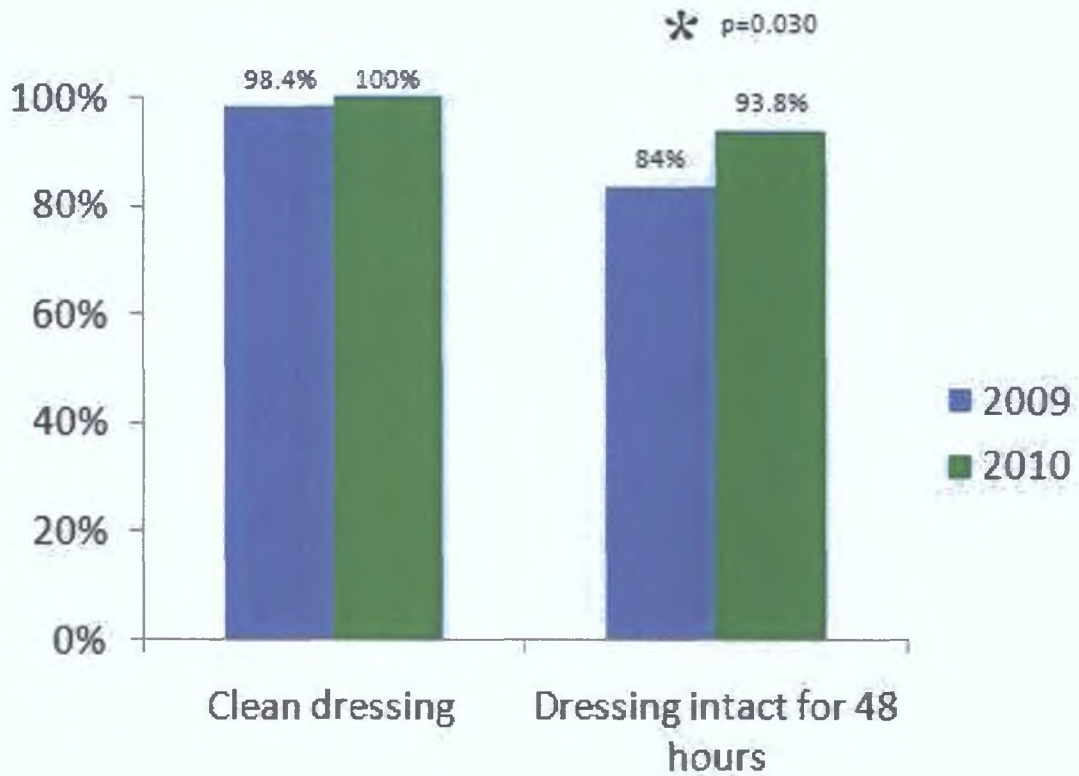
Of the surgical site dressings, 81 (76.4%) were reviewed at 48 hours post procedure. Of these 81 dressings, 76 (93.8%) had been left intact without being tampered with for the first 48 hours post procedure. This represented a statistically significant improvement on the 2009 results when only 83.5% of dressings were left intact for the first 48 hours ($p=0.030$) (Figure 5.2).

5.1.2. Catheter-related bloodstream infection

5.1.2.1. Peripheral venous catheter parameters

Over the three month repeat audit period a total of 295 PVC were assessed on surgical wards. Of these 251 (85.1%) were inserted during regular working hours (9am to 5pm), with the remainder ($n=44$, 14.9%) inserted during “on call” hours. With regard to the specialty of the teams inserting the PVC, 68 (23.1%) were inserted by the vascular surgery service, 64 (21.7%) by the colorectal surgery service and 55 (18.6%) by the upper gastrointestinal surgery team. Breast surgery PVC accounted for 46 (15.6%), with the remainder being inserted by medical ($n=51$, 17.3%) and orthopaedic teams ($n=3$, 1%), whose patients were outliers on general surgical wards and therefore included in the assessment.

Figure 5.2: Bar chart illustrating improvements in practice in relation to surgical site dressings from the initial 2009 audit to the repeat 2010 audit.



*=statistical significance

Of the 295 PVC assessed, 288 (97.6%) were observed to be covered by a clean intact dressing. This was a statistically significant improvement from 2009 when only 87.2% of PVC dressings were intact and clean ($p<0.001$).

With regard to duration of PVC, 286 of 295 (96.9%) were noted to be *in-situ* for less than 72 hours as per Beaumont Hospital guidelines. In the initial audit results in 2009 89.7% were noted to be *in-situ* for less than 72 hours. These data represent a statistically significant improvement ($p<0.001$).

As in the initial 2009 audit, the necessity of PVC was also assessed. A further statistically significant improvement was noted, with 223 (75.6%) of PVC deemed necessary compared with only 62.2% in the initial audit ($p=0.001$).

Of the 295 PVC examined, there were none associated with signs of phlebitis, and no PVC-related bloodstream infections were recorded during the three month audit. Although this represented an improvement from 2009 when three (1.1%) PVC were noted to be associated with signs of phlebitis, this was not statistically significant ($p=0.072$).

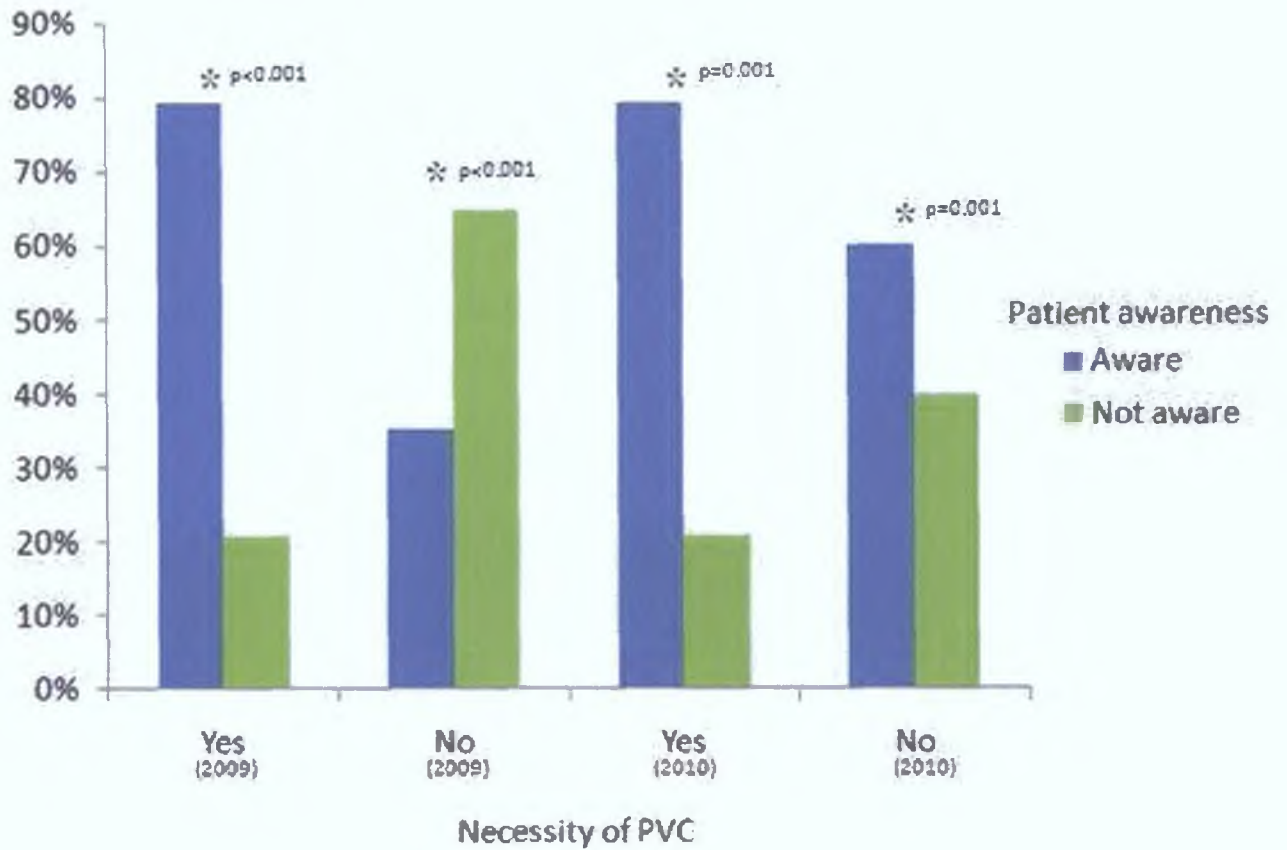
5.1.2.1.1. Patient awareness

Patient awareness as to the necessity of their PVC was assessed in 290 cases. Of these, 216 (74.5%) were noted to be aware of the need for their PVC, with 74 (25.5%) patients unaware. As was noted in 2009, again patient's lack of awareness as to the indication for their PVC

was significantly associated with the patient having an unnecessary PVC ($p=0.001$) (Figure 3). Furthermore when compared with the 2009 initial audit results, our data represents a statistically significant increase in patient awareness over the 12 months period, with patients in 2010 more likely to be aware of the necessity of their PVC (74.5% in 2010 compared with 62.4% in 2009; $p=0.006$) (Figure 5.3.).

Of 290 patients, 232 (78.6%) were asked whether they know their consultant's name; 186 (80.2%) were aware of their consultant's name while 46 (15.6%) were not. Knowledge of their consultants name was not associated with PVC necessity, duration or dressing quality.

Figure 5.3: The association of patient awareness and the necessity of a peripheral venous catheter both in 2009 (pre-intervention) and in 2010 (post-intervention).



*=statistical significance

5.1.2.2. Central venous catheter parameters

5.1.2.2.1. Central venous catheter maintenance parameters

In total 23 CVC were assessed on general surgical wards. Ten of these (43.5%) were under the care of the colorectal surgery team, four (17.4%) under the upper gastrointestinal surgery, three (13%) under vascular surgery and one (4.3%) under the care of the breast surgery service. The remaining five (21.7%) were *in-situ* in medical outliers on surgical wards.

All CVC were covered with a clean intact dressing. This improvement in practice as compared with the initial audit when 80% of dressings were intact and clean was statistically significant ($p=0.031$). Of those 23 CVC dressings, all had been changed within the preceding seven days, an improvement from the 2009 audit which was not found to be statistically significant ($p=0.332$). Of the 23 patients, seven were receiving TPN through their CVC. Of these, all had a designated TPN port.

With regard to patient awareness of necessity of their CVC, 21 (91.3%) patients were aware as to why their CVC was inserted, a non-significant ($p=0.502$) decrease from 96% in 2009. As in the initial audit, there were no significant associations between patient awareness of the indication for their CVC, the necessity of CVC and whether there was a clean dressing *in situ* which had been changed within the preceding seven days

5.1.2.3. Central venous catheter insertion parameters

Six CVC insertions were observed, all of which were inserted in a pre-operative elective setting by anaesthetists inserted in general surgical theatre. Of these five (83.3%) were inserted by registrars and one (16.7%) by a consultant anaesthetist. In all cases, the internal jugular vein was chosen as the insertion site, and a three lumen CVC was inserted.

5.1.2.3.1. Insertion site preparation

Chlorhexidine 2% was used in all cases and allowed to dry as per international recommendations. Appropriately sized drapes were used in all cases and the CVC site was covered with a transparent dressing (Tagaderm©) throughout. There were no statistical differences noted when compared to the results of the initial audit.

5.1.2.3.2. Practice of doctor inserting the central venous catheter

Appropriate hand hygiene was carried out in all cases pre-insertion (100%). However as in the initial 2009 audit, none of the doctors carried out hand hygiene post procedure (0%). With regard to appropriate attire, all doctors wore the cap and mask appropriately (100%), with five (83.3%) appropriately wearing a surgical gown. These data did not represent any statistically significant differences when compared to the 2009 audit results. However the number of observations, i.e. six, precluded the assessment of any statistically significant results.

5.2. Discussion

5.2.1. Surgical site infection prevention

5.2.1.1. Timing of surgical prophylaxis

These data represent a significant improvement in the timing of surgical prophylaxis and in the avoidance of tampering with surgical site dressings within the first 48 hours post procedure. The causes of SSI infection are multi-factorial and involve many, i.e. host, surgical and microbiological risk factors (Ayliffe, Babb et al. 1979; Mangram, Horan et al. 1999; Pittet, Hugonnet et al. 2000). In order to effect improvements in clinical practice, a targeted infection prevention and control programme is required, based on local assessments highlighting deficiencies in practice.

Best practice guidelines suggest administration of surgical prophylaxis within the 60 minutes prior to incision (Bratzler and Houck 2005; Forbes, Stephen et al. 2008). Furthermore it has been suggested that the administration of prophylaxis at 30 to 59 minutes pre-incision would be even more effective than antibiotics administered within 30 minutes of incision (Weber, Marti et al. 2008). Although it is well established that timely and appropriate administration of prophylactic antibiotics reduces SSI rate; ensuring proper administration of antibiotics before surgery continues to be a difficult challenge. It has previously been reported that much in-hospital antibiotic use is not in keeping with best practice guidelines and available data from clinical trials (Everitt, Soumerai et al. 1990; Whitman, Cowell et al. 2008).

Our data confirms improvements in practice, as overall only 30.5% of antibiotics were given pre-incision in our initial audit in 2009. After improvement following our educational

initiative, this percentage increased to 58.7%. In a more detailed analysis, our initial 2009 audit demonstrated that only 5.5% of prophylaxis administration occurred at 59-30 minutes pre-incision, and 25% less than 30 minutes before incision. The repeat audit after our educational intervention indicated that administration between 60 and 30 minutes pre-incision remained low despite an increase to 9.4%. However administration within 30 minutes of incision increased to 49.3% of cases ($p<0.001$). Although the aim of our educational intervention was to increase the proportion of surgical prophylaxis given between 59 and 30 minutes pre-incision, we effected only a minimal improvement in this area. However the overall proportion of surgical prophylaxis given in the 60 minutes pre-incision increased significantly. Furthermore the mean time of administration decreased to within 60 minutes before incision (6.2 minutes pre-incision) which is compliant with national best practice guidelines.

Previous education programmes to increase compliance regarding surgical prophylaxis have included person-to-person educational messages supplemented by printed reminders.(Everitt, Soumerai et al. 1990) A more recent prospective multi-site study specifically targeting deficiencies in the timing of prophylaxis demonstrated an improvement in surgical prophylaxis timing (van Kasteren, Mannien et al. 2005). This Dutch study improved adherence to best practice in prophylaxis timing from 39.4% to 51.8% ($p<0.01$). This improvement was effected through performance feedback to the surgical teams. In addition, a study of patients undergoing orthopaedic surgery demonstrated a significant improvement in prophylaxis timing through the use of a simple pre-operative checklist. Compliance improved from 65% to 97% ($p<0.001$) with a total of 479 cases assessed (Rosenberg, Wambold et al. 2008).

Other studies have targeted anaesthetists to improve the timing of surgical prophylaxis. One such study used a visual electronic reminder added to the anaesthesia information system. The authors demonstrated an increase in compliance with surgical prophylactic administration timing guidelines. This retrospective and prospective study reported that appropriate timing was increased by only 6.7% after the intervention, most likely since initial compliance levels before intervention were high at 82.4%. However, given the large numbers included in the study cohort (4,987 cases before the intervention and 9,478 cases afterwards) this increase was statistically significant ($p < 0.01$) (Wax, Beilin et al. 2007). A further study aimed at anaesthetic staff demonstrated improved compliance with prophylaxis timing guidelines from 69% to 92%. This was achieved through email based feedback to anaesthetic teams relating to prophylaxis timing over the preceding week. However the authors did not include any statistical analysis (O'Reilly, Talsma et al. 2006).

As in previous studies feedback to surgical teams is of critical importance in improving the timing of surgical prophylaxis. In our study this was specifically achieved through feedback of the initial 2009 audit results at grand rounds and at monthly clinical governance meetings. In addition the initial audit data detailing poor compliance regarding the timing of prophylaxis was also made available online through the SurgInfection website. The use of visual cues also previously commented on as an effective tool in improving prophylaxis timing was also implemented, with posters highly visible to both surgeons (in the scrub room) and anaesthetists (beside ventilation machines) placed in areas of theatre. As a result, our study has demonstrated improvements in the timing of prophylaxis administration comparable to and exceeding previously reported interventions in the published literature.

We recognise some limitations in this aspect of our study despite demonstrating a statistically significant improvement. The initiative focused solely on the promotion of best practice through increasing educational and awareness of those responsible for appropriate timing of prophylaxis. As such there was no specific pre-operative tool implemented such as a pre-operative checklist which has previously been shown to be effective.

5.2.1.2. Maintenance of surgical site dressings

Guidelines for best practice relating to post-operative wound care recommend clean intact surgical site dressings which remain *in-situ* without being tampered with for the first 48 hours post-operatively (Mangram, Horan et al. 1999). Following this initial 48 hour period there is no consensus on best practice and variability in surgical practice is common (O'Reilly, Talsma et al. 2006).

Previous initiatives to improve the care of the surgical site post-operatively have utilised a dressing change proforma with monthly medical chart audit and feedback to staff (O'Reilly, Talsma et al. 2006). In this prospective study following 58 patients after sternotomy, compliance with the standardised wound care protocol was 98%. However statistical analysis before and after the implementation was not reported upon.

A recent study assessed nursing practice on compliance with standardised practice in the care of 208 wounds both before and after an education intervention. The educational intervention

consisted of feedback of an initial audit, combined with visual aids detailing best practice in wound care. Although a decrease in rates of unnecessary dressing changes was reported, these results were not subjected to statistical analysis, and were based entirely upon survey responses by nursing staff rather than actual clinical assessment of wound care (Smith, Greenwood et al. 2010).

As previously reported our study also utilised the results of an initial audit to target deficiencies in post-operative wound care. Feedback to surgical teams of the 2009 audit data was carried out not only through the SurgInfection website but also at grand rounds and clinical governance meetings. Similar to studies commented upon previously, we also utilised visual cues in the form of posters in high visibility areas on surgical wards, recommending that surgical sites remain covered with a clean intact dressing for the first 48 hours post procedure without being tampered with. Through this initiative dressings remaining intact for the initial post-operative 48 hours increased from 83.5% to 93.8% ($p=0.03$). Also improvements were seen in the proportion of clean, intact dressings (100% from 98.4%). However given that the initial baseline rates of clean surgical site dressings were so high, the improvement in practice seen did not reach statistical significance.

5.2.2. Catheter related bloodstream infection prevention

Catheter-related bloodstream infections are a major source of preventable adverse events in hospital (Leape, Brennan et al. 1991; Barsuk, Cohen et al. 2009). More than 60% of patients admitted to hospital are likely to receive therapy via a peripheral IV cannula (Cook, Montori et al. 2004). Given the prevalence of PVCs amongst hospital patients, the prevention of PVC-

related blood stream infection is paramount both to provide safe patient care and to minimise hospital costs.

Our study demonstrates a significant decrease in both the numbers of unnecessary PVC as well as those remaining *in-situ* for longer than the 72 hours as recommended by Beaumont Hospital guidelines. The longer the patient has a PVC *in-situ* the greater the opportunity for micro-organisms to multiply (Curran, Coia et al. 2000). There have been few previous educational interventions to improve compliance with best practice in terms of the insertion and maintenance of PVC. One such study used a one hour lecture recommending the use of universal precautions for PVC placement. This survey demonstrated a modest increase in compliance of emergency department nursing personnel with best practice. However, these results were survey-based, were not found to be statistically significant and were focused on parameters associated with bloodborne infection prevention in the staff inserting the PVC (Baraff and Talan 1989).

There have been several education programmes based upon the prevention of CVC-related bloodstream infection. Sheretz et al used a one-day course on infection control practices and procedures to effect a significant decrease of 3.23 infections per 1000 catheter days ($p < 0.001$) (Sherertz, Ely et al. 2000). Similarly an educational program was developed incorporating slide shows and practical demonstrations in an ICU in Switzerland. Here a one-hour self study module aimed at surgical ICU nurses decreased CRBSI rates from 10.8 to 3.7 per 1,000 catheter days (Coopersmith, Rebmann et al. 2002; Warren, Zack et al. 2004). A further study of an education and a surveillance programme implemented in the ICU demonstrated a 77%

reduction in CVC related bloodstream infection through improving hand hygiene compliance amongst intensive care staff (Rosenthal, Guzman et al. 2006).

In our study, statistically significant differences were not seen with regard to the clinical effectiveness of our educational initiative as a result of small numbers. This highlights difficulties in auditing procedures which are carried out at unscheduled times, as is the case with CVC insertion in our institution, and when confined to one institution and one observer.

To our knowledge this is the first study to assess a significant clinical improvement in PVC care following a targeted intervention program. Given the success noted in CRBSI prevention through education in relation to CVC care, it is perhaps surprising that similar initiatives are not more widely reported upon regarding PVC-related bloodstream infection prevention.

Several recent studies have questioned current recommendations relating to the duration of PVC. At present, best practice guidelines recommend removal or routine replacement of PVCs after 72 hours (SARI 2009). A recent randomised controlled trial reported on 362 patients, 177 of whom were scheduled for routine replacement of PVC after 72 hours, with the remaining 185 randomised to have their PVC replaced on clinical indication. Overall no differences in CRBSI rates were noted between the two groups. (Rickard, McCann et al. 2010) A similar larger randomised controlled trial reported on 755 hospital inpatients, again randomised to either routine (at 72 hours) or clinically indicated PVC replacement. The rates of phlebitis between both groups were not statistically different (Webster, Clarke et al. 2008). In addition a recent Cochrane review encompassing 3408 patients found no conclusive

evidence of a benefit in changing PVC after 72 hours (Webster, Osborne et al. 2010). Despite these recent publications, Beaumont Hospital policy where this study was carried out recommends replacement of PVC routinely or removal of PVC after 72 hours. Considering that our policy recommends routine replacement the statistically significant decrease in numbers of PVC *in situ* for more than 72 hours represents an improvement in adherence to local best practice guidelines.

The infection prevention benefits of covering intravascular catheters with a clean intact dressing is one which is intuitive and recommended in both national and international guidelines as an essential component of CRBSI prevention (Mangram, Horan et al. 1999; Guideline 2008). As part of our educational intervention, we also demonstrated an improvement in adherence to these best practice guidelines, with 97.6% observed to be covered by a clean intact dressing compared with 87.2% before the educational intervention ($p < 0.001$). Interestingly, given that compliance with best practice in relation to PVC dressings was almost 90% in the initial audit, this parameter was not specifically targeted in lectures feeding back audit data, or indeed in posters placed on surgical wards. The importance of PVC dressings is commented upon in one specific section of the SurgInfection website only. Despite this relatively low level of importance placed upon this parameter it is interesting that a statistically significant benefit was noted. However, this may be explained by heightened awareness overall with regard to PVC care and the infection risk associated with them. In evolving a culture where the importance of CRBSI prevention is stressed, improvements in practice can be achieved as part of an overall behavioral change.

Irrespective of the clinical effect of decreasing numbers of PVC *in situ* for more than 72 hours, it is self evident that unnecessary PVC should be promptly removed in order to minimise CRBSI incidence. Our study demonstrates a significant decrease in the numbers of unnecessary PVC on surgical wards, from 37.8% to 24.4% ($p=0.001$). This not only reduces CRBSI risk but also represents a potential financial benefit for the healthcare system, avoiding the costs associated with PVC insertion and maintenance in cases where they are unnecessary. This is also likely to be welcomed by patients who would be spared the unnecessary pain of routine replacement in the absence of a continued indication for the PVC. However further progress in this area is required to reduce this to as near zero as possible.

In summary, these data represent translation of our educational initiative into clinical effectiveness. Statistically significant improvements were seen in parameters associated with SSI prevention, through improved timing of surgical prophylaxis and post operative wound care. This was achieved not by implementing a specific new pre- or post-operative checklist or bundle, but rather through creating a culture of safety by increasing knowledge and awareness of surgical site infection prevention measures among surgical staff. Similarly, with regard to CRBSI prevention, statistically significant improvements have been seen with regard to the necessity, duration and dressings of PVCs. Although our education programme targeted unnecessary PVC in particular, improving awareness regarding the infection risk posed by PVC has led to improvements in PVC management which were not specifically targeted, as seen in the increased proportion of PVC covered with a clean intact dressing. When implementing change in an immediate clinical setting such as a tertiary hospital it is inevitable that other initiatives to improve patient care are running in parallel. Particularly immediately prior to commencement of this study the hospital infection prevention and

control team introduced the use of peripheral venous catheter care bundles. Using these care bundles nursing staff collected data on PVCs and followed guidelines set out in the bundle with regard to maintenance and removal of the PVC. This may well have had a confounding effect on our own research, however our education programme targeted surgical doctors rather than nursing staff. Therefore while other activities in the hospital may have contributed to these improvements, e.g. the activity of the hospital's infection prevention and control team, the educational programme had a clear benefit. However the introduction of a checklist might improve compliance to near 100%. Checklists have been shown to be effective in improving infection prevention practices and improving patient safety. The WHO safe surgery saves lives checklist improved adherence to guidelines for administration of antibiotic prophylaxis pre-procedure, and ultimately led to decreased patient morbidity and mortality (Haynes, Weiser et al. 2009). Such a checklist centered entirely on infection prevention practices if implemented could improve compliance towards one hundred percent.

Chapter Six

Conclusions

6. Conclusions

The motivational factors influencing infection prevention and control behaviour are complex. (Nicol, Watkins et al. 2009) Multifaceted interventions utilizing a blended learning approach such as that detailed in this study are more likely to achieve success. Apart from education regarding HCAI, at a local level it is also important to stress the importance of HCAI as a quality and safety issue, as this is an area under-taught in our medical schools (O'Brien, Richards et al. 2009).

Many studies have shown how hospital costs are significantly reduced with education on infection prevention and control (Goetz, Kedzuef et al. 1999; Pittet, Mourouga et al. 1999; Sherertz, Ely et al. 2000; Coopersmith, Rebmann et al. 2002; Berenholtz, Pronovost et al. 2004; Topal, Conklin et al. 2005; Warren, Cosgrove et al. 2006). The costs of these educational interventions are small in comparison with the estimated savings (Pittet, Mourouga et al. 1999; Sherertz, Ely et al. 2000; Zack, Garrison et al. 2002; Warren, Zack et al. 2003). In these times of constrained financial resources, infection prevention and control measures become even more critical (Thorens, Kaelin et al. 1995; Fridkin, Pear et al. 1996; Archibald, Manning et al. 1997; Pittet, Mourouga et al. 1999). There is evidence in the literature to suggest that the most important factor in determining infection rates in surgical practice is the competence and conscientiousness of the individual surgeon (Mishriki, Law et al. 1990; Mishriki, Law et al. 1991). Even straightforward measures such as feedback of infection rates have been shown to decrease SSIs (Cruse and Foord 1980; van Kasteren, Mannien et al. 2005). Given the recent success of a unique education programme in educating surgeons (Howard, Williams et al. 2009), it is apparent that further such programmes could be effective in reducing morbidity and mortality for surgical patients. If such education

programmes were developed and were readily exportable across hospitals, regions, and countries, this would have positive financial implications for health services and for the quality and safety of patient care. It is with this in mind that this study was conceived.

Through a focussed education initiative, our study demonstrated significant improvements in a number of areas both in SSI and CRBSI prevention. Despite this many deficiencies remain. For example, intra-operatively we have shown that a significant proportion of patients do not have their intra-operative temperature maintained above 36C. There was no improvement in this area, despite posters, lectures and the website specifically targeting this area as a deficiency in practice. Another pre- or peri--operative parameter which could be improved is the timing of surgical prophylaxis. Although in this study a significant improvement was noted, with a higher proportion of antibiotics given pre-incision, the optimal time for incision is between 60 and 30 minutes pre-incision. With this in mind, there remains further room for improvement given that even post intervention less than 10% of prophylaxis was given during this optimal time window.

As with SSI, there remain areas for improvement in CRBSI prevention. With regard to PVC, we have demonstrated significant improvements in duration and dressing of PVCs. We have also shown a significant improvement through reducing the numbers of unnecessary cannula. However, optimally all PVC would be removed when no longer in use, and even post-intervention there remained a notable proportion of unnecessary PVC *in-situ* on surgical wards. Therefore further improvements are needed if we are to approach zero infections arising from 100% compliance as is required of healthcare bundles.

Our study affected change through increasing awareness and improving the knowledge of surgical trainees in the areas of SSI prevention and CRBSI prevention. Sustaining this change in behavior across the general surgical department remains a challenge. Continuing audit and re-audit, with feedback of results is essential to ensure that improvements in practice are long-lasting. There is a danger that the improvements noted in this study may be transient, and may not be sustained once the initial energy and attention of a newly launched interventional initiative dissipates. This is particularly an issue given the six or twelve month work contracts of non-consultant surgeons in each unit. Persistent emphasis of the importance of SSI and CRBSI prevention is essential to imbue the culture of safety amongst the new trainees when changeover occurs.

A further challenge remains to correct the deficiencies not improved through the current educational initiative. Issues such as the maintenance of patient normothermia are almost exclusively the responsibility of anaesthetic staff, and therefore incorporating anaesthetists into the educational initiative could improve this parameter. This could be achieved by feedback of audit data directly to anaesthetic trainees and consultants at monthly meetings. Although efforts were made to encourage anaesthetic staff to visit the SurgInfection website, further efforts such as individual emails, text messages or telephone calls with additional material of particular relevance to anaesthetic staff, could in theory improve the proportion of anaesthetic trainees accessing the website. Similarly, surgical prophylaxis administration, while ultimately the responsibility of the patient's surgical team to prescribe and ensure correct administration is often in real life clinical scenarios a shared responsibility with anaesthetic doctors. In effect more directly targeting anaesthetists like surgical trainees could

improve these intra-operative SSI prevention parameters. In this study however that was difficult. The study was carried out by a surgical trainee who had worked in the general surgery department for the year preceding the study. It was also co-supervised by the hospital's Professor of Surgery. As such it was well received by general surgical trainees in our institution, which no doubt facilitated the positive responses in clinical practice to the initiative noted in the repeat audit. The incorporation of anaesthetic trainees and heads of department into the actual continued promotion of this education initiative would improve its uptake amongst the doctors in that department, as it did in the general surgical department.

In addition to the above there are a number of other avenues to be explored as this initiative continues in the future. Using content from the website which has already proven effective in improving knowledge, a specific mandatory study module, is planned for development. This module will become part of first year basic surgical trainees online education through the Royal College of Surgeons in Ireland. This will also facilitate quantitative assessments of improvements in knowledge either through retrospective self-assessment or before-and-after measures of infection prevention and control knowledge and awareness, which will form part of individual trainee assessments of practice and competence.

Overall this study detailed the development, implementation and evaluation of a targeted blended learning initiative aimed at surgical trainees in a general surgical unit in a tertiary referral centre. Through this education initiative, a number of key parameters were noted to be poorly adhered to, and by specifically highlighting these areas to surgical trainees; statistically significant improvements in practice were noted in those areas. However due to constraints of time and resources it is not possible to determine if these were translated into

reduced infection rates. In the future, local expansion of this initiative could improve the practice of surgical trainees in other specialties and anesthesiology. On a national level, the development of a mandatory study module for first year basic surgical trainees will improve knowledge and awareness across a broader range of surgical doctors as well as provide an opportunity to quantitatively assess the effectiveness of the e-learning content on an individual level. Finally the impact of these and potential future additional interventions need to be assessed against and informed by outcome measures such as SSI rates, CRBSI rates and patient length of stay.

References:

- (28th August 2009). "National Statistics Omnibus Survey." Available online at
<http://www.statistics.gov.uk/cci/nugget.asp?ID=8>.
- (1996). "National Nosocomial Infections Surveillance (NNIS) report, data summary from October 1986-April 1996, issued May 1996. A report from the National Nosocomial Infections Surveillance (NNIS) System." Am J Infect Control **24**(5): 380-388.
- (2000). "National Nosocomial Infections Surveillance (NNIS) system report, data summary from January 1992-April 2000, issued June 2000." Am J Infect Control **28**(6): 429-448.
- (2001). "IOM committee calls for complete revamping of health care system to achieve better quality." Qual Lett Healthc Lead **13**(3): 14-15.
- (2008). "NICE clinical guideline 74 - Surgical site infection."
- Alfonso, J. L., S. B. Pereperez, et al. (2007). "Are we really seeing the total costs of surgical site infections? A Spanish study." Wound Repair Regen **15**(4): 474-481.
- Andrzejowski, J. C., D. Turnbull, et al. "A randomised single blinded study of the administration of pre-warmed fluid vs active fluid warming on the incidence of peri-operative hypothermia in short surgical procedures*." Anaesthesia.
- Archibald, L. K., M. L. Manning, et al. (1997). "Patient density, nurse-to-patient ratio and nosocomial infection risk in a pediatric cardiac intensive care unit." Pediatr Infect Dis J **16**(11): 1045-1048.
- Ayliffe, G. A. (1991). "Role of the environment of the operating suite in surgical wound infection." Rev Infect Dis **13 Suppl 10**: S800-804.
- Ayliffe, G. A., J. R. Babb, et al. (1979). "A unit for source and protective isolation in a general hospital." Br Med J **2**(6188): 461-465.

- Babcock, H. M., J. E. Zack, et al. (2004). "An educational intervention to reduce ventilator-associated pneumonia in an integrated health system: a comparison of effects." Chest **125**(6): 2224-2231.
- Baraff, L. J. and D. A. Talan (1989). "Compliance with universal precautions in a university hospital emergency department." Ann Emerg Med **18**(6): 654-657.
- Barsuk, J. H., E. R. Cohen, et al. (2009). "Use of simulation-based education to reduce catheter-related bloodstream infections." Arch Intern Med **169**(15): 1420-1423.
- Belda, F. J., L. Aguilera, et al. (2005). "Supplemental perioperative oxygen and the risk of surgical wound infection: a randomized controlled trial." Jama **294**(16): 2035-2042.
- Berenholtz, S. M., P. J. Pronovost, et al. (2004). "Eliminating catheter-related bloodstream infections in the intensive care unit." Crit Care Med **32**(10): 2014-2020.
- Bowater, R. J., S. A. Stirling, et al. (2009). "Is antibiotic prophylaxis in surgery a generally effective intervention? Testing a generic hypothesis over a set of meta-analyses." Ann Surg **249**(4): 551-556.
- Boyce, J. M. and D. Pittet (2002). "Guideline for Hand Hygiene in Health-Care Settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force." Infect Control Hosp Epidemiol **23**(12 Suppl): S3-40.
- Bratzler, D. W. and P. M. Houck (2005). "Antimicrobial prophylaxis for surgery: an advisory statement from the National Surgical Infection Prevention Project." Am J Surg **189**(4): 395-404.
- Bratzler, D. W. and D. R. Hunt (2006). "The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery." Clin Infect Dis **43**(3): 322-330.

- Burke, J. P. (2003). "Infection control - a problem for patient safety." N Engl J Med **348**(7): 651-656.
- Campbell, D. A., Jr., W. G. Henderson, et al. (2008). "Surgical site infection prevention: the importance of operative duration and blood transfusion--results of the first American College of Surgeons-National Surgical Quality Improvement Program Best Practices Initiative." J Am Coll Surg **207**(6): 810-820.
- Casey, A. L., L. A. Mermel, et al. (2008). "Antimicrobial central venous catheters in adults: a systematic review and meta-analysis." Lancet Infect Dis **8**(12): 763-776.
- Cercenado, E., J. Ena, et al. (1990). "A conservative procedure for the diagnosis of catheter-related infections." Arch Intern Med **150**(7): 1417-1420.
- Childs, S., E. Blenkinsopp, et al. (2005). "Effective e-learning for health professionals and students--barriers and their solutions. A systematic review of the literature--findings from the HeXL project." Health Info Libr J **22 Suppl 2**: 20-32.
- Chryso, E., E. Athanasakis, et al. (2005). "A prospective study comparing diathermy and scalpel incisions in tension-free inguinal hernioplasty." Am Surg **71**(4): 326-329.
- Classen, D. C., R. S. Evans, et al. (1992). "The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection." N Engl J Med **326**(5): 281-286.
- Clements, A. C., E. N. Tong, et al. (2007). "Risk stratification for surgical site infections in Australia: evaluation of the US National Nosocomial Infection Surveillance risk index." J Hosp Infect **66**(2): 148-155.
- Colombo, M., A. Maggioni, et al. (1997). "A randomized comparison of continuous versus interrupted mass closure of midline incisions in patients with gynecologic cancer." Obstet Gynecol **89**(5 Pt 1): 684-689.
- Cook, D. A., A. J. Levinson, et al. (2008). "Internet-based learning in the health professions: a meta-analysis." Jama **300**(10): 1181-1196.

- Cook, D. J., V. M. Montori, et al. (2004). "Improving patients' safety locally: changing clinician behaviour." Lancet **363**(9416): 1224-1230.
- Cooper, G. L. and C. C. Hopkins (1985). "Rapid diagnosis of intravascular catheter-associated infection by direct Gram staining of catheter segments." N Engl J Med **312**(18): 1142-1147.
- Coopersmith, C. M., T. L. Rebmann, et al. (2002). "Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit." Crit Care Med **30**(1): 59-64.
- Coopersmith, C. M., J. E. Zack, et al. (2004). "The impact of bedside behavior on catheter-related bacteremia in the intensive care unit." Arch Surg **139**(2): 131-136.
- Corman, M. L., M. C. Veidenheimer, et al. (1981). "Controlled clinical trial of three suture materials for abdominal wall closure after bowel operations." Am J Surg **141**(4): 510-513.
- Court-Brown, C. M. (1981). "Preoperative skin depilation and its effect on postoperative wound infections." J R Coll Surg Edinb **26**(4): 238-241.
- Cruse, P. J. and R. Foord (1980). "The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds." Surg Clin North Am **60**(1): 27-40.
- Curran, E. T., J. E. Coia, et al. (2000). "Multi-centre research surveillance project to reduce infections/phlebitis associated with peripheral vascular catheters." J Hosp Infect **46**(3): 194-202.
- Daetwyler, C. J., D. G. Cohen, et al. (2010). "eLearning to enhance physician patient communication: a pilot test of "doc.com" and "WebEncounter" in teaching bad news delivery." Med Teach **32**(9): e381-390.
- Darouiche, R. O., M. J. Wall, Jr., et al. (2010). "Chlorhexidine-Alcohol versus Povidone-Iodine for Surgical-Site Antisepsis." N Engl J Med **362**(1): 18-26.

- Davis, D. A., M. A. Thomson, et al. (1995). "Changing physician performance. A systematic review of the effect of continuing medical education strategies." Jama **274**(9): 700-705.
- Dawes, P. J. (2001). "Vestibular schwannoma screening: closing the audit loop." J Laryngol Otol **115**(9): 719-722.
- Dellinger, E. P., P. A. Gross, et al. (1994). "Quality standard for antimicrobial prophylaxis in surgical procedures. Infectious Diseases Society of America." Clin Infect Dis **18**(3): 422-427.
- Dellinger, E. P., P. A. Gross, et al. (1994). "Quality standard for antimicrobial prophylaxis in surgical procedures. The Infectious Diseases Society of America." Infect Control Hosp Epidemiol **15**(3): 182-188.
- Dellinger, E. P., S. M. Hausmann, et al. (2005). "Hospitals collaborate to decrease surgical site infections." Am J Surg **190**(1): 9-15.
- Dietrich, E. S., M. Demmler, et al. (2002). "Nosocomial pneumonia: a cost-of-illness analysis." Infection **30**(2): 61-67.
- Edgeworth, J. (2009). "Intravascular catheter infections." J Hosp Infect **73**(4): 323-330.
- Ehrenkranz, N. J. (1993). "Antimicrobial prophylaxis in surgery: mechanisms, misconceptions, and mischief." Infect Control Hosp Epidemiol **14**(2): 99-106.
- Everitt, D. E., S. B. Soumerai, et al. (1990). "Changing surgical antimicrobial prophylaxis practices through education targeted at senior department leaders." Infect Control Hosp Epidemiol **11**(11): 578-583.
- Fiorio, M., A. Marvaso, et al. (2006). "Incidence of surgical site infections in general surgery in Italy." Infection **34**(6): 310-314.

- Fitzpatrick, F., G. McIlvenny, et al. (2008). "Hospital infection society prevalence survey of Healthcare Associated Infection 2006: comparison of results between Northern Ireland and the Republic of Ireland." J Hosp Infect **69**(3): 265-273.
- Fitzpatrick, K. R., A. C. Pantle, et al. (2009). "Culture change for hand hygiene: clean hands save lives, part II." Med J Aust **191**(8 Suppl): S13-17.
- Fong, Y., M. F. Brennan, et al. (1996). "Drainage is unnecessary after elective liver resection." Am J Surg **171**(1): 158-162.
- Forbes, S. S., W. J. Stephen, et al. (2008). "Implementation of evidence-based practices for surgical site infection prophylaxis: results of a pre- and postintervention study." J Am Coll Surg **207**(3): 336-341.
- Ford, H. R., P. Jones, et al. (2005). "Intraoperative handling and wound healing: controlled clinical trial comparing coated VICRYL plus antibacterial suture (coated polyglactin 910 suture with triclosan) with coated VICRYL suture (coated polyglactin 910 suture)." Surg Infect (Larchmt) **6**(3): 313-321.
- Frank, S. M., L. A. Fleisher, et al. (1997). "Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events. A randomized clinical trial." Jama **277**(14): 1127-1134.
- Fridkin, S. K., S. M. Pear, et al. (1996). "The role of understaffing in central venous catheter-associated bloodstream infections." Infect Control Hosp Epidemiol **17**(3): 150-158.
- Fry, D. (2003). "Surgical site infection: Pathogenesis and prevention."
- Fung-Kee-Fung, M., J. Watters, et al. (2009). "Regional collaborations as a tool for quality improvements in surgery: a systematic review of the literature." Ann Surg **249**(4): 565-572.

- Gagliardi, A. R., C. Eskicioglu, et al. (2009). "Identifying opportunities for quality improvement in surgical site infection prevention." Am J Infect Control **37**(5): 398-402.
- Gallagher, G. A., T. McLintock, et al. (2003). "Closing the audit loop--prevention of perioperative hypothermia: audit and reaudit of perioperative hypothermia." Eur J Anaesthesiol **20**(9): 750-752.
- Gilliam, A. D., W. J. Speake, et al. (2003). "Finding the best from the rest: evaluation of the quality of patient information on the Internet." Ann R Coll Surg Engl **85**(1): 44-46.
- Goetz, A. (1999). "Feedback to nursing staff as an intervention to reduce catheter-associated urinary tract infections." AJIC **27**(5): 402-404.
- Goetz, A. M., S. Kedzuf, et al. (1999). "Feedback to nursing staff as an intervention to reduce catheter-associated urinary tract infections." Am J Infect Control **27**(5): 402-404.
- Gottrup, F. (2000). "Prevention of surgical-wound infections." N Engl J Med **342**(3): 202-204.
- Gottrup, F. (2005). "Wound healing and principles of wound closure." The Scandinavian Handbook of Plastic Surgery.
- Guideline, N. (2008). "National Institute for Health and Clinical Excellence. Surgical site infection. 2008. (Clinical guideline 74.)."
- Haley, R. W., D. H. Culver, et al. (1985). "The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals." Am J Epidemiol **121**(2): 182-205.
- Harbarth, S., H. Sax, et al. (2003). "The preventable proportion of nosocomial infections: an overview of published reports." J Hosp Infect **54**(4): 258-266; quiz 321.
- Hardin, W. (1997). Handwashing and patient skin preparation. In: Malangoni MA, ed. Critical Issues in Operating Room Management. Philadelphia, Lipincott-Raven.

- Harris, S., M. Morgan, et al. (2008). "Web-based reporting of the results of the 2006 four country prevalence survey of healthcare associated infections." J Hosp Infect **69**(3): 258-264.
- Haynes, A. B., T. G. Weiser, et al. (2009). "A surgical safety checklist to reduce morbidity and mortality in a global population." N Engl J Med **360**(5): 491-499.
- Hernandez, K., E. Ramos, et al. (2005). "Incidence of and risk factors for surgical-site infections in a Peruvian hospital." Infect Control Hosp Epidemiol **26**(5): 473-477.
- Hockenhull, J. C., K. Dwan, et al. (2008). "The clinical effectiveness and cost-effectiveness of central venous catheters treated with anti-infective agents in preventing bloodstream infections: a systematic review and economic evaluation." Health Technol Assess **12**(12): iii-iv, xi-xii, 1-154.
- Hoe, N. Y. and R. Nambiar (1985). "Is preoperative shaving really necessary?" Ann Acad Med Singapore **14**(4): 700-704.
- Hollenbeak, C. S., D. Murphy, et al. (2002). "Nonrandom selection and the attributable cost of surgical-site infections." Infect Control Hosp Epidemiol **23**(4): 177-182.
- Howard, D. P., C. Williams, et al. (2009). "A simple effective clean practice protocol significantly improves hand decontamination and infection control measures in the acute surgical setting." Infection **37**(1): 34-38.
- Humphreys, H. (2009). "Preventing surgical site infection. Where now?" J Hosp Infect **73**(4): 316-322.
- Hunt, T. K., B. Zederfeldt, et al. (1969). "Oxygen and healing." Am J Surg **118**(4): 521-525.
- Ichikawa, S., M. Ishihara, et al. (2007). "Prospective study of antibiotic protocols for managing surgical site infections in children." J Pediatr Surg **42**(6): 1002-1007; discussion 1007.

- Ishizuka, M., H. Nagata, et al. (2008). "Total parenteral nutrition is a major risk factor for central venous catheter-related bloodstream infection in colorectal cancer patients receiving postoperative chemotherapy." Eur Surg Res **41**(4): 341-345.
- Jamtvedt, G., J. M. Young, et al. (2006). "Audit and feedback: effects on professional practice and health care outcomes." Cochrane Database Syst Rev(2): CD000259.
- Jordan, G. H. (1999). "Techniques of tissue handling and transfer." J Urol **162**(3 Pt 2): 1213-1217.
- Kawai, M., M. Tani, et al. (2006). "Early removal of prophylactic drains reduces the risk of intra-abdominal infections in patients with pancreatic head resection: prospective study for 104 consecutive patients." Ann Surg **244**(1): 1-7.
- Kaye, K. S., K. Schmit, et al. (2005). "The effect of increasing age on the risk of surgical site infection." J Infect Dis **191**(7): 1056-1062.
- Kearns, S. R., E. M. Connolly, et al. (2001). "Randomized clinical trial of diathermy versus scalpel incision in elective midline laparotomy." Br J Surg **88**(1): 41-44.
- Kernodle D.S., K. A. B. (1995). Surgical and trauma-related infections. New York, Churchill Livingstone.
- Kilgore, M. and S. Brossette (2008). "Cost of bloodstream infections." Am J Infect Control **36**(10): S172 e171-173.
- Kilgore, M. L., K. Ghosh, et al. (2008). "The costs of nosocomial infections." Med Care **46**(1): 101-104.
- Kirkland, K. B., J. P. Briggs, et al. (1999). "The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs." Infect Control Hosp Epidemiol **20**(11): 725-730.

- Kurz, A., D. I. Sessler, et al. (1996). "Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group." N Engl J Med **334**(19): 1209-1215.
- Lange, B. J., M. Weiman, et al. (1997). "Impact of changes in catheter management on infectious complications among children with central venous catheters." Infect Control Hosp Epidemiol **18**(5): 326-332.
- Leape, L. L., T. A. Brennan, et al. (1991). "The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II." N Engl J Med **324**(6): 377-384.
- Leaper, D., S. Burman-Roy, et al. (2008). "Prevention and treatment of surgical site infection: summary of NICE guidance." Bmj **337**: a1924.
- Leaper DJ, G. F. (1998). "Surgical wounds." Wounds: biology and management: 23-40.
- Lim, J., A. Phillips, et al. "Use of the world wide web by cardiac surgery patients." Interact Cardiovasc Thorac Surg.
- Liu, C. L., S. T. Fan, et al. (2004). "Abdominal drainage after hepatic resection is contraindicated in patients with chronic liver diseases." Ann Surg **239**(2): 194-201.
- Lorente, L., C. Henry, et al. (2005). "Central venous catheter-related infection in a prospective and observational study of 2,595 catheters." Crit Care **9**(6): R631-635.
- Lyon, U. o. (2004). Improving Patient Safety in Europe.
- Maki, D. G. and M. Ringer (1991). "Risk factors for infusion-related phlebitis with small peripheral venous catheters. A randomized controlled trial." Ann Intern Med **114**(10): 845-854.

- Mangram, A. J., T. C. Horan, et al. (1999). "Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee." Infect Control Hosp Epidemiol **20**(4): 250-278; quiz 279-280.
- Masterson, T. M., G. T. Rodeheaver, et al. (1984). "Bacteriologic evaluation of electric clippers for surgical hair removal." Am J Surg **148**(3): 301-302.
- McCleary, A. J. and S. Raptis (2001). "Closing the loop: the role of audit in reducing groin complications associated with coronary angiography." Clin Radiol **56**(11): 917-921.
- McGuckin, M., A. Taylor, et al. (2004). "Evaluation of a patient education model for increasing hand hygiene compliance in an inpatient rehabilitation unit." Am J Infect Control **32**(4): 235-238.
- McGuckin, M., R. Waterman, et al. (1999). "Patient education model for increasing handwashing compliance." Am J Infect Control **27**(4): 309-314.
- McGuckin, M., R. Waterman, et al. (2001). "Evaluation of a patient-empowering hand hygiene programme in the UK." J Hosp Infect **48**(3): 222-227.
- McNeil, P. M. and H. J. Sugerman (1986). "Continuous absorbable vs interrupted nonabsorbable fascial closure. A prospective, randomized comparison." Arch Surg **121**(7): 821-823.
- Meeks, D. W., K. P. Lally, et al. "Compliance with guidelines to prevent surgical site infections: As simple as 1-2-3?" Am J Surg.
- Melling, A. C., B. Ali, et al. (2001). "Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial." Lancet **358**(9285): 876-880.
- Merad, F., J. M. Hay, et al. (1999). "Is prophylactic pelvic drainage useful after elective rectal or anal anastomosis? A multicenter controlled randomized trial. French Association for Surgical Research." Surgery **125**(5): 529-535.

- Merad, F., E. Yahouchi, et al. (1998). "Prophylactic abdominal drainage after elective colonic resection and suprapromontory anastomosis: a multicenter study controlled by randomization. French Associations for Surgical Research." Arch Surg **133**(3): 309-314.
- Meylan, G. and P. Tschantz (2001). "[Surgical wounds with or without dressings. Prospective comparative study]." Ann Chir **126**(5): 459-462.
- Miller, E., D. E. Paull, et al. (1988). "Scalpel versus electrocautery in modified radical mastectomy." Am Surg **54**(5): 284-286.
- Mishriki, S. F., D. J. Law, et al. (1990). "Factors affecting the incidence of postoperative wound infection." J Hosp Infect **16**(3): 223-230.
- Mishriki, S. F., D. J. Law, et al. (1991). "Surgical audit: variations in wound infection rates of individual surgeons." J R Coll Surg Edinb **36**(4): 251-253.
- Mody, L., S. A. McNeil, et al. (2003). "Introduction of a waterless alcohol-based hand rub in a long-term-care facility." Infect Control Hosp Epidemiol **24**(3): 165-171.
- Mohanna, K. (2007). "The use of elearning in medical education." Postgrad Med J **83**(978): 211.
- NICE (2008). "Prevention and treatment of surgical site infection."
- Nichols, R. L. (1989). "Antibiotic prophylaxis in surgery." J Chemother **1**(3): 170-178.
- Nicol, P. W., R. E. Watkins, et al. (2009). "The power of vivid experience in hand hygiene compliance." J Hosp Infect **72**(1): 36-42.
- O'Brien, D., J. Richards, et al. (2009). "Survey of teaching/learning of healthcare-associated infections in UK and Irish medical schools." J Hosp Infect **73**(2): 171-175.
- O'Grady, N. P., M. Alexander, et al. (2002). "Guidelines for the prevention of intravascular catheter-related infections." Infect Control Hosp Epidemiol **23**(12): 759-769.

- O'Reilly, M., A. Talsma, et al. (2006). "An anesthesia information system designed to provide physician-specific feedback improves timely administration of prophylactic antibiotics." Anesth Analg **103**(4): 908-912.
- Pastor, C., J. H. Baek, et al. "Validation of the risk index category as a predictor of surgical site infection in elective colorectal surgery." Dis Colon Rectum **53**(5): 721-727.
- Pereira, L. J., G. M. Lee, et al. (1990). "The effect of surgical handwashing routines on the microbial counts of operating room nurses." Am J Infect Control **18**(6): 354-364.
- Perencevich, E. N., K. E. Sands, et al. (2003). "Health and economic impact of surgical site infections diagnosed after hospital discharge." Emerg Infect Dis **9**(2): 196-203.
- Pittet, D., S. Hugonnet, et al. (2000). "Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection Control Programme." Lancet **356**(9238): 1307-1312.
- Pittet, D., P. Mourouga, et al. (1999). "Compliance with handwashing in a teaching hospital. Infection Control Program." Ann Intern Med **130**(2): 126-130.
- Prasad, N., D. Sunderamoorthy, et al. (2006). "Secondary prevention of fragility fractures: are we following the guidelines? Closing the audit loop." Ann R Coll Surg Engl **88**(5): 470-474.
- Pratt, R. J., C. M. Pellowe, et al. (2007). "epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England." J Hosp Infect **65 Suppl 1**: S1-64.
- Price, P. (1938). "Bacteriology of normal skin: a new quantitative test applied to a study of the bacterial flora and the disinfectant action of mechanical cleansing. ." J Infect Dis **63**: 301-318.
- Pronovost, P., D. Needham, et al. (2006). "An intervention to decrease catheter-related bloodstream infections in the ICU." N Engl J Med **355**(26): 2725-2732.

- Richards, P. C., C. M. Balch, et al. (1983). "Abdominal wound closure. A randomized prospective study of 571 patients comparing continuous vs. interrupted suture techniques." Ann Surg **197**(2): 238-243.
- Rickard, C. M., D. McCann, et al. (2010). "Routine resite of peripheral intravenous devices every 3 days did not reduce complications compared with clinically indicated resite: a randomised controlled trial." BMC Med **8**: 53.
- Rojanapirom, S. and S. Danchaivijitr (1992). "Pre-operative shaving and wound infection in appendectomy." J Med Assoc Thai **75 Suppl 2**: 20-23.
- Rosenberg, A. D., D. Wambold, et al. (2008). "Ensuring appropriate timing of antimicrobial prophylaxis." J Bone Joint Surg Am **90**(2): 226-232.
- Rosenberger, L. H., A. D. Politano, et al. (2011). "The surgical care improvement project and prevention of post-operative infection, including surgical site infection." Surg Infect (Larchmt) **12**(3): 163-168.
- Rosenthal, V. D., S. Guzman, et al. (2006). "Impact of an infection control program on rates of ventilator-associated pneumonia in intensive care units in 2 Argentinean hospitals." Am J Infect Control **34**(2): 58-63.
- Rosenthal, V. D., S. Guzman, et al. (2005). "The attributable cost and length of hospital stay because of nosocomial pneumonia in intensive care units in 3 hospitals in Argentina: a prospective, matched analysis." Am J Infect Control **33**(3): 157-161.
- Ross, A. and J. Crumpler (2007). "The impact of an evidence-based practice education program on the role of oral care in the prevention of ventilator-associated pneumonia." Intensive Crit Care Nurs **23**(3): 132-136.
- Ruiz, J. G., M. J. Mintzer, et al. (2006). "The impact of E-learning in medical education." Acad Med **81**(3): 207-212.

- Safdar, N. and C. Abad (2008). "Educational interventions for prevention of healthcare-associated infection: a systematic review." Crit Care Med **36**(3): 933-940.
- Sahlin, S., J. Ahlberg, et al. (1993). "Monofilament versus multifilament absorbable sutures for abdominal closure." Br J Surg **80**(3): 322-324.
- Sanderson, P. J. (1993). "Antimicrobial prophylaxis in surgery: microbiological factors." J Antimicrob Chemother **31 Suppl B**: 1-9.
- SARI (2009). Prevention of Intravascular Catheter-related Infection in Ireland. HSE/HPSE, Health Protection Surveillance Centre 2009.
- SARI (2009). "Prevention of Intravascular Catheter-related Infection Sub-Committee." Prevention of Intravascular Catheter-related infections in Ireland.
- Scher, K. S. (1997). "Studies on the duration of antibiotic administration for surgical prophylaxis." Am Surg **63**(1): 59-62.
- Schmied, H., A. Kurz, et al. (1996). "Mild hypothermia increases blood loss and transfusion requirements during total hip arthroplasty." Lancet **347**(8997): 289-292.
- Sebben, J. E. (1988). "Electrosurgery principles: cutting current and cutaneous surgery--Part II." J Dermatol Surg Oncol **14**(2): 147-150.
- Seiler, C. M., T. Bruckner, et al. (2009). "Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: a multicenter randomized trial (INSECT: ISRCTN24023541)." Ann Surg **249**(4): 576-582.
- Sellick, J. A., Jr., M. Stelmach, et al. (1991). "Surveillance of surgical wound infections following open heart surgery." Infect Control Hosp Epidemiol **12**(10): 591-596.
- Semmelweis, I. (1983). Etiology, Concept, and Prophylaxis of Childbed Fever. Madison, WI, The University of Wisconsin Press.

- Serra-Aracil, X., M. I. Garcia-Domingo, et al. (2011). "Surgical site infection in elective operations for colorectal cancer after the application of preventive measures." Arch Surg **146**(5): 606-612.
- Shamim, M. (2009). "Diathermy vs. scalpel skin incisions in general surgery: double-blind, randomized, clinical trial." World J Surg **33**(8): 1594-1599.
- Sheikh, B. (2004). "Safety and efficacy of electrocautery scalpel utilization for skin opening in neurosurgery." Br J Neurosurg **18**(3): 268-272.
- Sherertz, R. J., E. W. Ely, et al. (2000). "Education of physicians-in-training can decrease the risk for vascular catheter infection." Ann Intern Med **132**(8): 641-648.
- Shojania, K. G., B. W. Duncan, et al. (2001). "Making health care safer: a critical analysis of patient safety practices." Evid Rep Technol Assess (Summ)(43): i-x, 1-668.
- Smith, G., M. Greenwood, et al. (2010). "Ward nurses' use of wound dressings before and after a bespoke education programme." J Wound Care **19**(9): 396-402.
- Smyth, E. T., G. McIlvenny, et al. (2008). "Four country healthcare associated infection prevalence survey 2006: overview of the results." J Hosp Infect **69**(3): 230-248.
- Snow, M., G. L. White, Jr., et al. (2006). "Mentor's hand hygiene practices influence student's hand hygiene rates." Am J Infect Control **34**(1): 18-24.
- Stolz, A. J., J. Schutzner, et al. (2004). "[Is a scalpel required to perform a thoracotomy?]." Rozhl Chir **83**(4): 185-188.
- Tanner, J., S. Swarbrook, et al. (2008). "Surgical hand antisepsis to reduce surgical site infection." Cochrane Database Syst Rev(1): CD004288.
- Taylor, L. and S. Jones (2006). "Clinical governance in practice: closing the loop with integrated audit systems." J Psychiatr Ment Health Nurs **13**(2): 228-233.
- Thompson, B. L., D. M. Dwyer, et al. (1997). "Handwashing and glove use in a long-term-care facility." Infect Control Hosp Epidemiol **18**(2): 97-103.

- Thorens, J. B., R. M. Kaelin, et al. (1995). "Influence of the quality of nursing on the duration of weaning from mechanical ventilation in patients with chronic obstructive pulmonary disease." Crit Care Med **23**(11): 1807-1815.
- Topal, J., S. Conklin, et al. (2005). "Prevention of nosocomial catheter-associated urinary tract infections through computerized feedback to physicians and a nurse-directed protocol." Am J Med Qual **20**(3): 121-126.
- Tourmousoglou, C. E., E. Yiannakopoulou, et al. (2008). "Adherence to guidelines for antibiotic prophylaxis in general surgery: a critical appraisal." J Antimicrob Chemother **61**(1): 214-218.
- Trimbos, J. B., I. B. Smit, et al. (1992). "A randomized clinical trial comparing two methods of fascia closure following midline laparotomy." Arch Surg **127**(10): 1232-1234.
- van 't Riet, M., E. W. Steyerberg, et al. (2002). "Meta-analysis of techniques for closure of midline abdominal incisions." Br J Surg **89**(11): 1350-1356.
- van Kasteren, M. E., B. J. Kullberg, et al. (2003). "Adherence to local hospital guidelines for surgical antimicrobial prophylaxis: a multicentre audit in Dutch hospitals." J Antimicrob Chemother **51**(6): 1389-1396.
- van Kasteren, M. E., J. Mannien, et al. (2005). "Quality improvement of surgical prophylaxis in Dutch hospitals: evaluation of a multi-site intervention by time series analysis." J Antimicrob Chemother **56**(6): 1094-1102.
- Vilar-Compte, D., R. Roldan-Marin, et al. (2006). "Surgical site infection (SSI) rates among patients who underwent mastectomy after the introduction of SSI prevention policies." Infect Control Hosp Epidemiol **27**(8): 829-834.
- Warren, D. K., S. E. Cosgrove, et al. (2006). "A multicenter intervention to prevent catheter-associated bloodstream infections." Infect Control Hosp Epidemiol **27**(7): 662-669.

- Warren, D. K., J. E. Zack, et al. (2003). "An educational intervention to prevent catheter-associated bloodstream infections in a nonteaching, community medical center." Crit Care Med **31**(7): 1959-1963.
- Warren, D. K., J. E. Zack, et al. (2004). "The effect of an education program on the incidence of central venous catheter-associated bloodstream infection in a medical ICU." Chest **126**(5): 1612-1618.
- Wax, D. B., Y. Beilin, et al. (2007). "The effect of an interactive visual reminder in an anesthesia information management system on timeliness of prophylactic antibiotic administration." Anesth Analg **104**(6): 1462-1466, table of contents.
- Weber, W. P., W. R. Marti, et al. (2008). "The timing of surgical antimicrobial prophylaxis." Ann Surg **247**(6): 918-926.
- Webster, J., S. Clarke, et al. (2008). "Routine care of peripheral intravenous catheters versus clinically indicated replacement: randomised controlled trial." BMJ **337**: a339.
- Webster, J., S. Osborne, et al. (2010). "Clinically-indicated replacement versus routine replacement of peripheral venous catheters." Cochrane Database Syst Rev **3**: CD007798.
- Whitman, G., V. Cowell, et al. (2008). "Prophylactic antibiotic use: hardwiring of physician behavior, not education, leads to compliance." J Am Coll Surg **207**(1): 88-94.
- Wisplinghoff, H., T. Bischoff, et al. (2004). "Nosocomial bloodstream infections in US hospitals: analysis of 24,179 cases from a prospective nationwide surveillance study." Clin Infect Dis **39**(3): 309-317.
- Wissing, J., T. J. van Vroonhoven, et al. (1987). "Fascia closure after midline laparotomy: results of a randomized trial." Br J Surg **74**(8): 738-741.

- Won, S. P., H. C. Chou, et al. (2004). "Handwashing program for the prevention of nosocomial infections in a neonatal intensive care unit." Infect Control Hosp Epidemiol **25**(9): 742-746.
- Wong, E. S. (1999). "The price of a surgical-site infection: more than just excess length of stay." Infect Control Hosp Epidemiol **20**(11): 722-724.
- Wong, G., T. Greenhalgh, et al. "Internet-based medical education: a realist review of what works, for whom and in what circumstances." BMC Med Educ **10**: 12.
- Woodhead, K., E. W. Taylor, et al. (2002). "Behaviours and rituals in the operating theatre. A report from the Hospital Infection Society Working Party on Infection Control in Operating Theatres." J Hosp Infect **51**(4): 241-255.
- Yilmaz, G., R. Caylan, et al. (2007). "Effect of education on the rate of and the understanding of risk factors for intravascular catheter-related infections." Infect Control Hosp Epidemiol **28**(6): 689-694.
- Zack, J. E., T. Garrison, et al. (2002). "Effect of an education program aimed at reducing the occurrence of ventilator-associated pneumonia." Crit Care Med **30**(11): 2407-2412.

Appendix

7.1. Publications, presentations and awards associated with this thesis

7.1.1. Peer-reviewed publications

McHugh SM, Hill ADK, Humphreys H. Prevention of healthcare-associated infection through education: Have surgeons been overlooked? *The Surgeon*. 2010 Apr;8(2):96-100. PMID: 20303891

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H. A targeted e-learning programme for surgical trainees to enhance patient safety in preventing surgical infection. *J Contin Educ Health Prof*. 2010 Fall;30(4):257-9.

McHugh SM, Corrigan MA, Dimitrov BD, Morris-Downes M, Fitzpatrick F, Cowman S, Tierney S, Hill ADK, Humphreys H. The prevention of peripheral vascular catheter-related bloodstream infection: The potential role of patient awareness. *Infect Control Hosp Epidemiol*. 2011 Jan;32(1):95-6. Epub 2010 Nov 18

McHugh SM, Hill AD, Humphreys H. Intraoperative technique as a factor in the prevention of surgical site infection. *J Hosp Infect*. 2011 May;78(1):1-4. Epub 2011 Mar 1.

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill AD, Humphreys H. Preventing infection in general surgery: improvements through education of surgeons by surgeons. *J Hosp Infect*. 2011 Aug;78(4):312-6

McHugh SM, Collins CJ, Corrigan MA, Hill AD, Humphreys H. The role of topical antibiotics used as prophylaxis in surgical site infection prevention. J Antimicrob Chemother. 2011 Apr;66(4):693-701. Epub 2011 Feb 3. Review

7.1.2. Presentations

7.1.2.1. National oral presentations

An audit of peripheral venous catheter use in surgical patients: more work to be done

McHugh SM, Cowman S, Tierney S, Hill ADK, Humphreys H. Department of Surgery, Department of Microbiology, School of Nursing, Royal College of Surgeons in Ireland

Sylvester O'Halloran Surgical Meeting 2010

The timing of surgical prophylaxis: Is the Safe Surgery Saves Lives Checklist enough to ensure best practice?

McHugh S, Corrigan MA, Cowman S, Tierney S, Broe P, Hill ADK, Humphreys H. Departments of Surgery, Royal College of Surgeons in Ireland and Beaumont Hospital, Departments of Microbiology Royal College of Surgeons in Ireland and Beaumont Hospital, Department of Nursing, Royal College of Surgeons in Ireland.

35th Sir Peter Freyer Memorial Lecture & Surgical Symposium 2010

An audit of operative note quality in a general surgery unit

McHugh S, Rowland P, Hill ADK, Humphreys H. Departments of Surgery and Microbiology, Beaumont Hospital and Royal College of Surgeons in Ireland, Dublin 9

35th Sir Peter Freyer Memorial Lecture & Surgical Symposium 2010

7.1.2.2. International oral presentations

The prevention of peripheral catheter-related bloodstream infection: An assessment of best practice and patient awareness

McHugh SM, Corrigan MA, Dimitrov BD, Morris-Downes M, Fitzpatrick F, Cowman S, Tierney S, Hill ADK, Humphreys H. Departments of Surgery & Microbiology, Beaumont Hospital & Royal College of Surgeons in Ireland

American College of Surgeons Clinical Congress, Washington, September 2010

A two year initiative to improve patients care through decreasing surgical infection

Seamus Mark Mc Hugh, Mark Corrigan, Borislav Dimitrov, Seamus Cowman, Sean Tierney. Arnold Hill, Hilary Humphreys. Royal College of Surgeons in Ireland, Dublin, Ireland.

European Society of Surgery Meeting, Turin, November 2010

Improving patient safety by preventing surgical infection – Results of a two year initiative

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H

Royal College of Surgeons in Ireland, Dublin, Ireland.

Society for Academics & Research in Surgery (SARS), January 2011

7.1.2.3. Poster presentations

A targeted e-learning programme for surgical trainees

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H.

Departments of Surgery, Royal College of Surgeons in Ireland and Beaumont Hospital,

Departments of Microbiology Royal College of Surgeons in Ireland and Beaumont Hospital,

Department of Nursing, Royal College of Surgeons in Ireland.

National Academy for Integration of Research, Teaching and Learning Conference, held in the R.C.S.I. October 2010

The potential role of patient awareness in the prevention of peripheral catheter-related bloodstream infection

McHugh, S; Corrigan, M; Dimitrov, B; Morris-Downes, M; Fitzpatrick, F; Cowman, S;

Tierney, S; Hill, A; Humphreys, H. Departments of Surgery and Microbiology, Royal College of Surgeons in Ireland and Beaumont Hospital

7th International Conference of the Hospital Infection Society 2010

Attitudes, awareness and knowledge of healthcare-associated infection among consultant surgeons in the Republic of Ireland

O'Brien, D; McHugh, S; Hill, A; Humphreys, H. Departments of Surgery and Microbiology, Royal College of Surgeons in Ireland and Beaumont Hospital

7th International Conference of the Hospital Infection Society 2010

Development of a Targeted E-learning Programme for Surgical Infection Prevention

McHugh, S; Corrigan, M; Cowman, S; Tierney, S; Dimitrov, B; Hill, A; Humphreys, H. Departments of Surgery and Microbiology, Royal College of Surgeons in Ireland and Beaumont Hospital

7th International Conference of the Hospital Infection Society 2010

Can a pre-operative checklist ensure best practice in surgical prophylaxis administration?

McHugh, S; Corrigan, M; Cowman, S; Tierney, S; Broe, P; Hill, A; Humphreys, H. Departments of Surgery and Microbiology, Royal College of Surgeons in Ireland and Beaumont Hospital

7th International Conference of the Hospital Infection Society 2010

Improving surgical practice and reducing hospital infection through education

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H.
Departments of Surgery and Microbiology, Royal College of Surgeons in Ireland and
Beaumont Hospital

XXth Waterford Surgical Meeting 2010

7.1.3. Awards



Awarded Commendation for “Best Hospital Project” at the Irish Healthcare Awards 2010

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H -
Improving surgical practice and reducing hospital infection through education

Poster prize winner XXth Waterford Surgical Meeting 2010

McHugh SM, Corrigan MA, Dimitrov BD, Cowman S, Tierney S, Hill ADK, Humphreys H -
Improving surgical practice and reducing hospital infection through education

7.2.2. Post-operative data

 Peripheral Venous Catheter Form 	
Audit Details Ward <input type="text"/> <input type="text"/> <input type="text"/> Date <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
IV Line 1	
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/>
Timing of insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/>	Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/>
Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine	Creating IV intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/>
Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/>
If unnecessary, why was the IV originally placed: <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
IV Line 2	
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/>
Timing of insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/>	Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/>
Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine	Creating IV intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/>
Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/>
If unnecessary, why was the IV originally placed: <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
IV Line 3	
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/>
Timing of insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/>	Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/>
Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine	Creating IV intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/>
Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/>
If unnecessary, why was the IV originally placed: <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
IV Line 4	
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/>
Timing of insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/>	Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/>
Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine	Creating IV intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/>
Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/>
If unnecessary, why was the IV originally placed: <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	
IV Line 5	
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/>
Timing of insertion: 9-5 <input type="checkbox"/> On call <input type="checkbox"/>	Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/>
Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine	Creating IV intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/>
Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/>
If unnecessary, why was the IV originally placed: <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	

7.2.4. Central venous catheter maintenance data

Audit Details		Date:	11111055	
CVC Line 1				
Need for CVC has been reviewed today: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Designated port for TPN: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	N/A: <input type="checkbox"/>
Crossing is changed within last 7 days: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Crossing intact and clean: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	
Patient aware of need for CVC: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Speciality of Team: <input type="checkbox"/> Breast	<input type="checkbox"/> Vascular	<input type="checkbox"/> Colorectal
Patient knows consultant's name: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	<input type="checkbox"/> Upper GI	<input type="checkbox"/> Ortho	<input type="checkbox"/> Medicine
CVC Line 2				
Need for CVC has been reviewed today: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Designated port for TPN: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	N/A: <input type="checkbox"/>
Crossing is changed within last 7 days: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Crossing intact and clean: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	
Patient aware of need for CVC: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Speciality of Team: <input type="checkbox"/> Breast	<input type="checkbox"/> Vascular	<input type="checkbox"/> Colorectal
Patient knows consultant's name: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	<input type="checkbox"/> Upper GI	<input type="checkbox"/> Ortho	<input type="checkbox"/> Medicine
CVC Line 3				
Need for CVC has been reviewed today: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Designated port for TPN: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	N/A: <input type="checkbox"/>
Crossing is changed within last 7 days: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Crossing intact and clean: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	
Patient aware of need for CVC: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Speciality of Team: <input type="checkbox"/> Breast	<input type="checkbox"/> Vascular	<input type="checkbox"/> Colorectal
Patient knows consultant's name: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	<input type="checkbox"/> Upper GI	<input type="checkbox"/> Ortho	<input type="checkbox"/> Medicine
CVC Line 4				
Need for CVC has been reviewed today: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Designated port for TPN: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	N/A: <input type="checkbox"/>
Crossing is changed within last 7 days: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Crossing intact and clean: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	
Patient aware of need for CVC: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	Speciality of Team: <input type="checkbox"/> Breast	<input type="checkbox"/> Vascular	<input type="checkbox"/> Colorectal
Patient knows consultant's name: Yes <input type="checkbox"/>	No: <input type="checkbox"/>	<input type="checkbox"/> Upper GI	<input type="checkbox"/> Ortho	<input type="checkbox"/> Medicine

7.2.5. Peripheral venous catheter maintenance data

Peripheral Venous Catheter Form		GC14052
Audit Details: Ward <input type="text"/> Cat <input type="text"/>		
IV Line 1		
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of insertion: 9-5 <input type="checkbox"/> Out call <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Dressing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: <input type="text"/>	
IV Line 2		
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of insertion: 9-5 <input type="checkbox"/> Out call <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Dressing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: <input type="text"/>	
IV Line 3		
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of insertion: 9-5 <input type="checkbox"/> Out call <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Dressing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: <input type="text"/>	
IV Line 4		
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of insertion: 9-5 <input type="checkbox"/> Out call <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Dressing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: <input type="text"/>	
IV Line 5		
Patient aware of need for IV cannula: Yes <input type="checkbox"/> No <input type="checkbox"/> Timing of insertion: 9-5 <input type="checkbox"/> Out call <input type="checkbox"/> Speciality of Team: <input type="checkbox"/> Breast <input type="checkbox"/> Vascular <input type="checkbox"/> Colorectal <input type="checkbox"/> Upper GI <input type="checkbox"/> Ortho <input type="checkbox"/> Medicine Patient knows consultant's name: Yes <input type="checkbox"/> No <input type="checkbox"/>	Need for IV use has been reviewed today: Yes <input type="checkbox"/> No <input type="checkbox"/> Duration < 72 Hours: Yes <input type="checkbox"/> No <input type="checkbox"/> Dressing is intact and clean: Yes <input type="checkbox"/> No <input type="checkbox"/> Evidence of IV line infection: Yes <input type="checkbox"/> No <input type="checkbox"/> If unnecessary, why was the IV originally placed: <input type="text"/>	

7.3. Example of HTML code

This code was written to design the "Contact Us" page of the website

```
<html>

<head>
    <title>Surginfection</title>
</head>
<body>
<div id="Layer1" style="position: absolute; left: 208px; top: 43px; width: 302px; height: 48px; z-
index: 6; visibility: visible; background-color: #FFFFFF; layer-background-color: #FFFFFF; border: 1px
none #000000;"> </div>
</body>
</html>
<table width="100%" height="94" cellpadding="0" cellspacing="0" border="0">
    <tr valign="top">
        <td width="246"
height="94"><div align="center"></div></td>
        <td width="368"
height="94"></td>
    <td width="100%"
height="94" background="topbar1bg.jpg">&nbsp;</td>
    </tr>
</table>
<table width="100%" height="33" cellpadding="0" cellspacing="0" border="0">
    <tr valign="top">
        <td width="246"
height="33"><a href="guidelines.php"></a></td>
        <td width="368"
height="33"></td>
    <td width="100%"
height="33" background="3buttonareabg.jpg">&nbsp;</td>
    </tr>
</table>
<table width="100%" cellpadding="0" cellspacing="0" border="0">
    <tr valign="top">
        <td width="207"
height="725">
<p><a href="tutorials.php"></a><BR>
    <a href="cases.php"></a><BR>
    <a href="videos.php"></a><BR>
    <a href="podcasting.php"></a><BR>
```

```
<a href="aboutus.php"></a><BR>
```

```
<a href="contactus.php"></a><a href="links.php"></a><BR>
```

```
<a href="index.php"></a><BR>
```

```
<td width="100%">
```

```
<table width="100%" cellpadding="10" cellspacing="0" border="0">
```

```
<tr valign="top">
```

```
<td height="725">
```

```
<table width="100%" cellpadding="2" cellspacing="2" border="0">
```

```
<tr valign="top">
```

```
<td width="72%"><H3 class="style12">Welcome to our site</h3>
```

```
<p class="style14"><span class="style13">Seamus McHugh</span> is a postgraduate research fellow in general surgery.</p>
```

```
<p class="style14">As part of a two year project, he is designing an education programme aimed at preventing infection in surgical patients</p>
```

```
<p>&nbsp;</p>
```

```
<p class="style14">Reach him here:</p>
```

```
<form name="form1" method="get" action="uploadnew1.php">
```

```
<p class="style5"> Name:
```

```
<input type="text" name="name">
```

```
<p align="left"><br>
```

```
<span class="style5">Email:</span>
```

```
<input type="text" name="email">
```

```
<p align="left"><span class="style5">Text:</span><br>
```

```
<textarea name="comment" cols="50" rows="10"></textarea>
```

```
</p>
```

```
<p><br>
```

```
<input type="submit" name="Submit" value="Send">
```

```
</p>
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7.4. Posters used during this study

7.4.1. Posters placed on surgical wards

You only need to wait

48 HRS.

Tampering with wound dressings within 48 hours of surgery increases wound infection rates

www.surginfection.com

Even one unwashed hand can have disastrous consequences

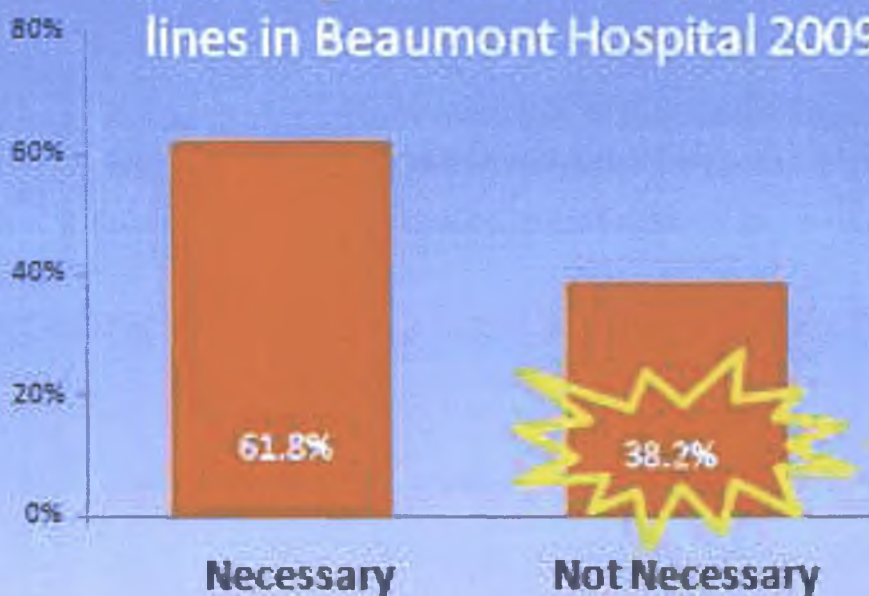


Wash your hands BEFORE and AFTER patient contact to prevent infection

www.surginfection.com

Remove unnecessary peripheral lines

Percentage of necessary peripheral lines in Beaumont Hospital 2009



On ward rounds, check whether your patients peripheral line can be removed

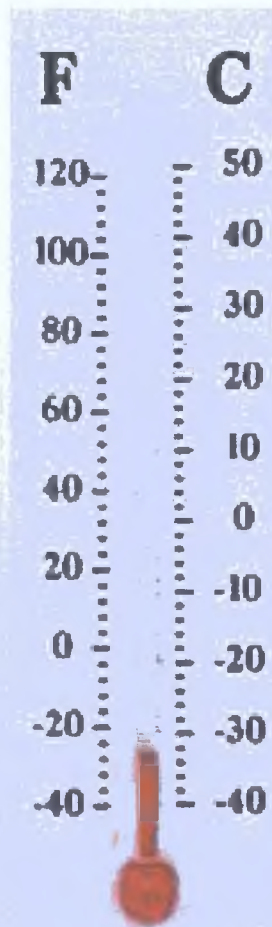


www.surgInfection.com

7.4.2. Posters placed in general surgery theatres

Global Warming

Keeping your patients
body temperature
above 36°C during
surgery decreases their
risk of wound infection



Use Bair® Huggers and Fluid warmers where
necessary

www.surginfection.com

Timing is everything...



Give antibiotics **BEFORE** the start of surgery

Delays put your patient at risk of infection

www.surgInfection.com

Timing is everything...



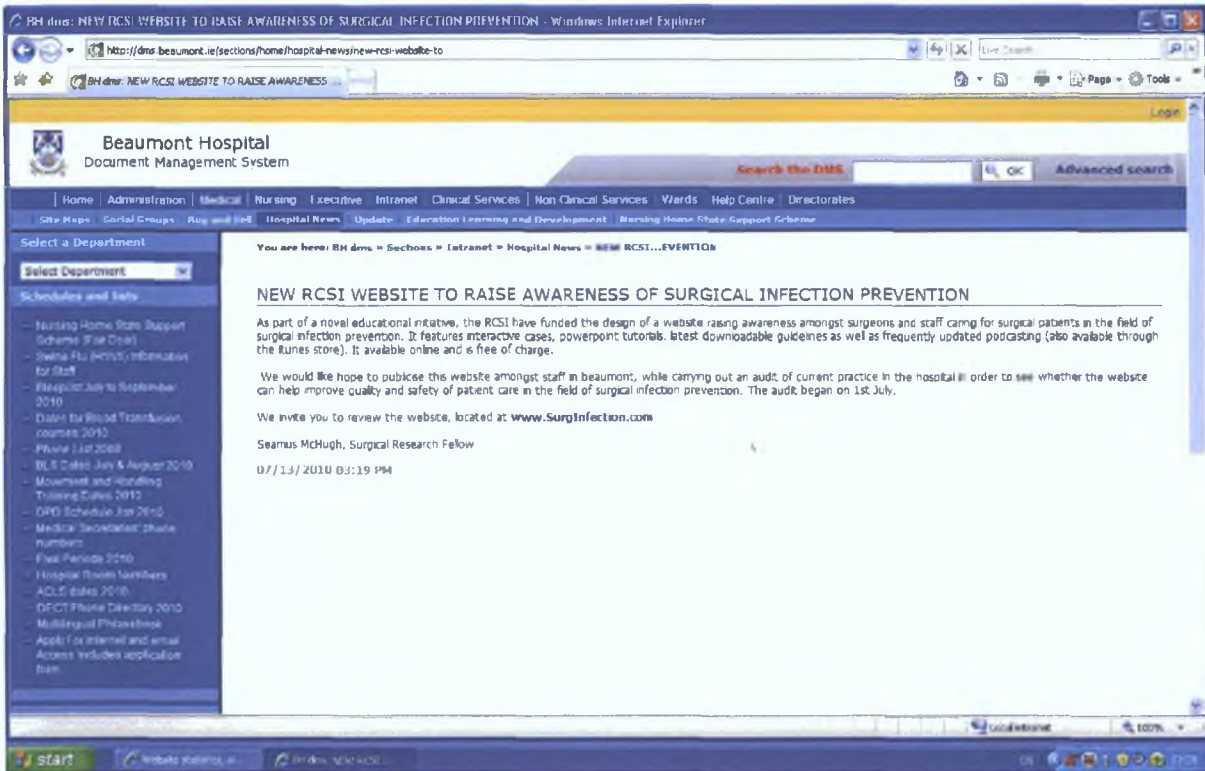
Give antibiotics BEFORE the start of surgery

Delays put your patient at risk of infection

www.surginfection.com

7.5. Local and national promotion of the study

7.5.1. Announcement on Beaumont Hospital Intranet



7.5.2. Announcement on Royal College of Surgeons website

The screenshot shows the website of the Royal College of Surgeons in Ireland (RCSI) as viewed in Internet Explorer. The browser's address bar shows the URL <http://www.rcsi.ie/>. The website header features the RCSI logo and the text "Royal College of Surgeons in Ireland" and "Coláiste Ríogla na Máinici na Éireann". A navigation menu on the right lists various sections: About the College, Admissions, Alumni and Development, Careers, Contact Us, Library, Members and Fellows, News and Events, Postgraduate Examinations, Prescriptive Students, and Sitemap. Below the header is a horizontal menu with links to Home, Medical and Health Sciences, Surgery and Postgraduate Faculties, Research, and RCSI International. A search bar and a "Take me to" dropdown are also present. The main content area is divided into two columns. The left column contains a "Welcome to the Royal College of Surgeons in Ireland" section, followed by a paragraph about the college's history and a "Read more about us" link. The right column features a "Latest News and Events" section dated Monday, July 19, 2010, with a headline about a course on infection prevention. Below the news is a small image of a surgeon in an operating room. The Windows taskbar at the bottom shows the Start button, the active browser window, and the system tray with the date and time.

Royal College of Surgeons in Ireland *Coláiste Ríogla na Máinici na Éireann*

Home Medical and Health Sciences Surgery and Postgraduate Faculties Research RCSI International


Take me to

Welcome to the Royal College of Surgeons in Ireland

For over two hundred years RCSI has played a major role in medical education and training in Ireland. Founded in 1784 to train surgeons, a medical school was later established in 1886. Today RCSI has schools of Pharmacy, Physiotherapy, Nursing and healthcare management. In addition to Undergraduate education RCSI delivers postgraduate training and education through its Faculties of Radiology, Dentistry, Sports & Exercise Medicine and the school of Postgraduate Studies. The RCSI Research Institute is one of Ireland's foremost research centres.

Building on our heritage in surgery, we will enhance human health through endeavour, innovation and collaboration in education, research and service.

Read more about us:


 **Safe Patient Care Course:** RCSI and NPSC will be jointly hosting a 5 day course on healthcare-associated infection prevention and control for all in September 2010. [Click here for further details.](#)

Latest News and Events - Monday, July 19, 2010

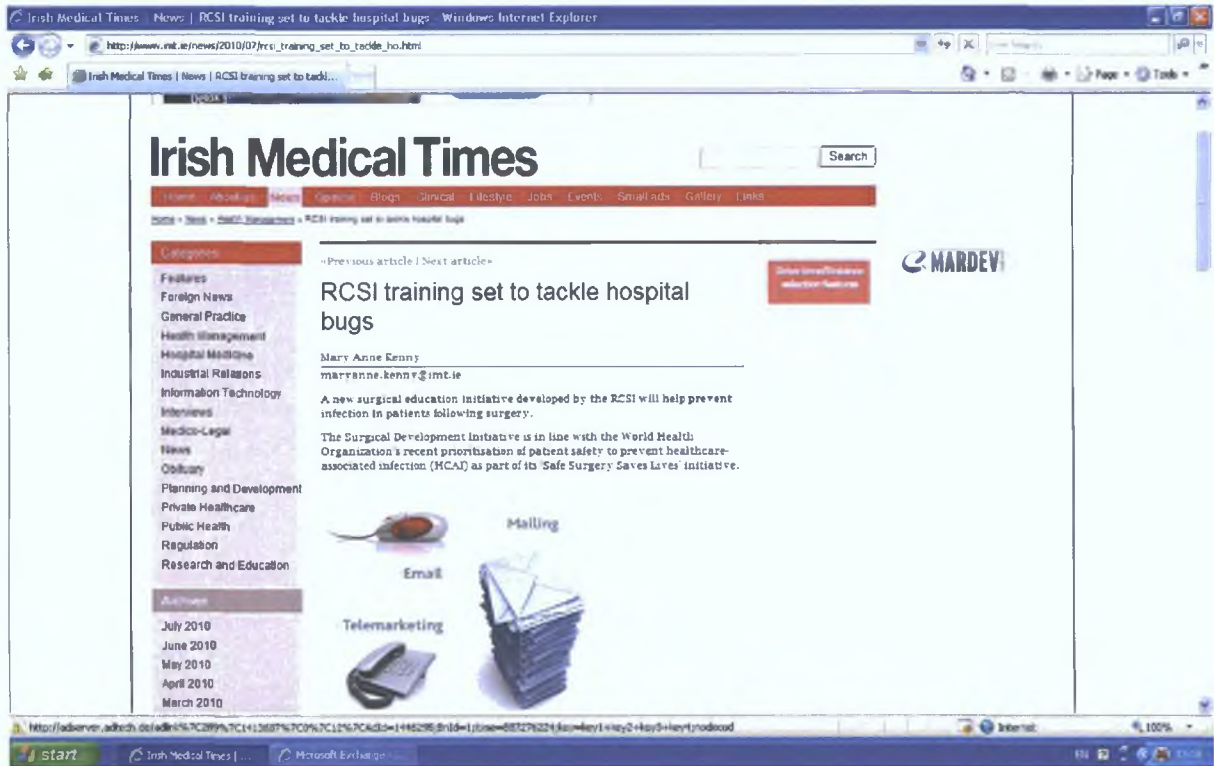
19th July 2010 - RCSI initiative to prevent infection following surgery and maximize patient safety

The Royal College of Surgeons in Ireland (RCSI) is launching a new education initiative for trainee surgeons to help prevent infection in patients following surgery and to improve patient safety.

[For more information please click here.](#)



7.5.3. Article in the Irish Medical Times website



7.5.4. National newspaper articles

Daily Mail

Date 20 July 2010
Page 17



newspaper licensing agency

Doctors to get special lessons on scrubbing up

By Petrina Vowden
Health Editor

WASHING your hands isn't exactly brain surgery, but our future surgeons will have to undergo a special course to learn how to do it properly.

The Royal College of Surgeons in Ireland has introduced an online programme to help protect patients against hospital superbugs. It will test students' skills and knowledge of the institute's rules and guidelines to ensure patient safety.

The 85 trainee surgeons who start their back surgical training at the RCSI this month will be the first to use the new programme.

They will be able to see ex-ruminate videos and podcasts and reviews of all the latest published guidelines on surgical infection prevention.

Infections linked to health care affect about one in 15 patients admitted to our hospitals.

Proper hand washing by staff, patients and visitors are key measures in the fight against

these infections, but a 2007 study at University College Cork showed that most of the Irish doctors and students were not washing their hands.

Stop Infections Now founder, Dr Teresa Graham, welcomed the programme.

She said: "The more surgeons are made aware and educated about prevention and patient safety the better."

"But my main worry is, no matter how many standards and guidelines are introduced to see if surveillance or strict enforcement of them."

HEALTH EDITOR'S PICK

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MEDICINE Surgeons told how to beat bugs

By SAM HARRISON

TRADE surgeons are to be taught how to protect their hands from bacteria, according to a new study.

The initiative has been launched by the Royal College of Surgeons in Ireland and aims to provide hand hygiene education to 10,000 surgeons and medical students.

Prof Henry Hamlyn, president of the RCSI, said: "It is essential to ensure that surgeons are fully equipped to protect their patients and advance the standards of medical care wherever possible."

"Education is the key to success in any profession and we are delighted to be able to provide this education to our surgeons."

The initiative will be funded by the RCSI and the Department of Health. It will be a joint effort between the RCSI and the Department of Health.

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Headline: Surgeon training aims to reduce infection risk and improve patient safety

Surgeon training aims to reduce infection risk and improve patient safety

By Evelyn Ring

A NEW education programme for trainee surgeons aimed at reducing infectious risk and improving patient safety is being launched this month.

The new initiative, developed by the Royal College of Surgeons in Ireland (RCSI), builds on the World Health Organisation's (WHO) 'Safe Surgery Saves Lives' initiative. Those starting their traineeship training this month will participate in the new teaching programme.

The web-based initiative has been developed to improve hand hygiene and make optimal use of antibiotics before surgery to prevent infection.

It also focuses on the care of surgical sites after surgery and the prevention of bloodstream infection that can result from infected intravascular devices, such as catheters or 'drugs'.

RCSI professor of surgery Arnold Hill said the initiative was in line with the WHO's recent proclamation of patient safety to prevent health-care-associated infection and its Safe Surgery Saves Lives that was endorsed by the RCSI.

Head of clinical microbiology at RCSI Prof Hilary Hungate said the college was committed to promoting safe surgery and advocating the highest standards of surgical care for patients.

"Education to improve practice is a key component in preventing health-care-associated infection and this RCSI initiative will maintain patient safety by enhancing the education of surgical trainees."

The teaching programme will assess the

trainee's current practice, their knowledge of interventions to minimise hospital-acquired infections and facilities access to national and international guidelines. Healthcare-associated infection differs between one in 10 and one in 20 patients admitted to acute hospitals.

RCSI has carried out an audit of surgical practice and this will be repeated following the delivery of the teaching programme to measure the effectiveness of the initiative.

available at www.sciencedirect.com

The Surgeon, Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland

www.thesurgeon.net

Review

Preventing healthcare-associated infection through education: Have surgeons been overlooked?

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ABSTRACT

Background/aims: Some 20–30% of HCAI are considered to be preventable through an extensive infection prevention and control programme. Through an extensive literature review we aim to critically appraise studies which have utilised education initiatives to decrease HCAI.

Methods: An extensive review of the literature was carried out in both online medical journals and through the Royal College of Surgeons in Ireland library.

Findings: Many studies over the last 10 years have demonstrated success in educating nursing staff, critical care healthcare workers as well as medical students and junior doctors in the infection prevention and control of infection. Comparatively few have focussed on surgical trainees. A blended learning approach, with particular focus on the small group format is important. Interventions involving web-based learning in combination with established education formats are proving successful in changing behaviour.

Conclusions: The development of an educational strategy for surgical trainees focussing on infection prevention and control is overdue. Such a programme would have far reaching benefits for individual patients, contribute to significant economic savings within health services and enhance the quality and safety of patient care.

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Introduction

Healthcare-associated infection (HCAI) is associated with considerable morbidity and mortality to patients. The recent Hospital Infection Society Prevalence Survey (HISPS) of HCAI, which was carried out in England, Wales, Northern Ireland and the Republic of Ireland and which involved 75,694

patients, noted a prevalence overall of 4.9%, with the figure increasing to 6% in tertiary referral centres.¹ The Prevalence Survey of Nosocomial Infections in Spain (EPINI) using a common methodology published in 2006 revealed an HCAI rate of 7.90%.² The total number of patients acquiring HCAI in the European Union every year is estimated at 3 million, with 50,000 deaths per year as a consequence.³

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Original Research

A Targeted E-Learning Program for Surgical Trainees to Enhance Patient Safety in Preventing Surgical Infection

SEAMUS MARK McHUGH, MB, BCh, BAQ, MRCSI; MARK CORREGAN, MD, MRCSI; BORESLAV DIMITROV, PhD; PROFESSOR SEAMUS COWLIAN, MSc, PhD; PROFESSOR SEAN TIERNEY, BSc, MCh, FRCSI; PROFESSOR HILARY HUMPHREYS, MD, FRCP(I); PROFESSOR ARNOLD HILL, MCh, FRCSI

Introduction: Surgical site infection accounts for 20% of all health care-associated infections (HCAIs), however, a program incorporating the education of surgeons has yet to be established across the specialty.

Methods: An audit of surgical practice in infection prevention was carried out in Beaumont Hospital from July to November 2009. An educational Web site was developed targeting deficiencies highlighted in the audit. Interactive clinical cases were constructed using PHP coding, an HTML-embedded language, and then linked to a MySQL relational database. PowerPoint tutorials were produced as online Flash audiovisual movies. An online repository of streaming videos demonstrating best practice was made available, and weekly podcasts were made available on the iTunes store for free download. Usage of the e-learning program was assessed quantitatively over 6 weeks in May and June 2010 using the commercial company HitScan.

Results: During the 5-month audit, deficiencies in practice were highlighted, including the timing of surgical prophylaxis (33% noncompliance) and intravenous catheter care in surgical patients (38% noncompliance regarding necessity). Over the 6-week assessment of the educational material, the SurgInfection.com Web pages were accessed more than 8000 times; 77.8% of the visitors were from Ireland. The most commonly accessed modality was the repository with interactive clinical cases, accounting for 3463 (43% of the Web site visits). The average user spent 57 minutes per visit, with 30% of them visiting the Web site multiple times.

Discussion: Interactive virtual cases mirroring real-life clinical scenarios are likely to be successful as an e-learning modality. User-friendly interfaces and 24-hour accessibility will increase uptake by surgical trainees.

Key Words: e-learning, infection prevention, surgical training, health-care-associated infection

Introduction

Approximately 30% of health care-associated infectious (HCAIs) are preventable by infection prevention and control programs.¹ Surgical site infection (SSI) accounts for 20% of all HCAIs,² and effective education for surgeons

Disclaimer: The authors report none.

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is an essential part of any strategy to reduce SSI and other surgical infections. The motivational factors influencing infection prevention and control behavior are complex.³ As such, interventions need to be multifaceted to achieve success. Studies have shown that the traditional approach of lecture-based education alone does not result in meaningful behavioral changes.⁴ As technology improves, education programs to change behavior become more innovative. Novel approaches include high-fidelity simulation to improve adherence to best practice in clinical performance,^{5,7} as well as e-learning.

E-learning involves the use of Internet technology to enhance knowledge, offering students control over learning content and allowing them to tailor their learning sequence individually.⁸ The last 5 years have seen an increasing profile for e-learning in educating medical students and in facilitating the continuing professional development (CPD) of health care professionals.⁹ Notable with regard to infection prevention in surgical patients is a Web-based training module incorporating lectures and posters regarding surgical intensive care unit physicians and nurses decreased catheter-related bloodstream infection (CI) from 11.3 per 1,000 catheter days.

5. Hiddon AJ, Kouznetsov EV, Halverson R, et al. Risk factors for colonization with methicillin-resistant *Staphylococcus aureus* (MRSA) in patients admitted to an urban hospital: emergence of community-associated MRSA nasal carriage. *Clin Infect Dis* 2005;41(2):159-166.
6. Peterson LR, Hartz DM, Babcock A. 5-Minute lives campaign case study: an MRSA intervention at Evanston Northwestern Healthcare. *J Comm J Oral Public Saf* 2007;33(12):732-738.
7. Warren DK, Cuda RM, Cooper-Smith CM, Merr LB, Zack JE, Fraser VL. Epidemiology of methicillin-resistant *Staphylococcus aureus* colonization in a surgical intensive care unit. *Infect Control Hosp Epidemiol* 2006;27(10):1032-1040.
8. Haley OC, Mittal D, Lavoielette A, Jazmiparsedy S, Parvez N, Haley RW. Methicillin-resistant *Staphylococcus aureus* infection or colonization present at hospital admission: multivariable risk factor screening to increase efficiency of surveillance culturing. *J Clin Microbiol* 2007;45(9):3031-3033.
9. Heymann DL. *Control of Communicable Diseases Manual*, 18th ed. Washington, DC: American Public Health Association; 2004.
10. Elston DM. Community-acquired methicillin-resistant *Staphylococcus aureus*. *J Am Acad Dermatol* 2007;56(1):1.

Role of Patient Awareness in Prevention of Peripheral Vascular Catheter-Related Bloodstream Infection

Catheter-related bloodstream infections account for 7% of all healthcare-associated infections.¹² Interventions to prevent bloodstream infections that are associated with peripheral venous catheters (PVCs) include appropriate hand hygiene, aseptic technique, skin asepsis, and daily PVC review.²⁴ Best practice guidelines suggest that, in the absence of a dedicated intravenous catheter monitoring team, the duration of cannulation should be limited to 72 hours or less.²⁵ Recently, healthcare providers have involved patients in playing a more active role in ensuring that best practice is followed by healthcare workers. Partners in Your Care, a US patient education behavioral model for increasing hand hygiene adherence and for empowering patients with responsibility for their own care, has increased hand hygiene adherence among healthcare workers.²⁶ Similar patient-empowering programs have yet to be developed for other aspects of healthcare-associated infection prevention, including prevention of catheter-related bloodstream infections. The objective of our study was to review adherence to best practice guidelines for the prevention of PVC-associated infection and to determine whether patient awareness of the indication for cannulation had an influence on PVC care.

Beaumont Hospital (Dublin, Ireland) is a 631-bed, acute tertiary referral hospital with national centers for neurosurgery, renal, pancreas, and small bowel transplantation, and cochlear implantation. The study was performed on 4 general surgical wards from July 1 through November 30, 2009. Specific data collection forms were designed using Teleform data capture software (Cardiff). Data were obtained from the pa-

tient's medical chart and from ward nursing staff. Patient awareness of the indication for PVC placement was assessed by questioning the patient. Patients unable to communicate their awareness of the indication for PVC insertion or their consultant's name were excluded from further analyses. The analysis was based on the PVC (case level) rather than on the patient—that is, patients with more than 1 PVC had their PVCs assessed independently. The necessity for the PVC was prospectively assessed—that is, a PVC inserted initially for intravenous antibiotics that were subsequently discontinued was deemed to be unnecessary. Peripherally placed central venous catheters were excluded from the study. Statistical analysis was performed using Excel 2007 (Microsoft) and SPSS, version 17 (SPSS), with $P < .05$ considered to be statistically significant.

In total, 275 PVCs were assessed. Of these, 104 (38%) were no longer required ("unnecessary"), and 171 (62%) were considered to be still necessary. Patients were questioned on the indication for their PVC in 178 cases; for 97 PVCs, it was not possible to question the patient. Although 111 (62%) of the 178 patients were aware of the reason for their PVC, 67 (38%) were not. The patient's lack of awareness of the indication for their PVC was significantly associated with the patient having an unnecessary PVC in situ ($P < .001$). Patients who were unaware of the reason for their intravenous catheter cannula were approximately 7 times more likely (odds ratio, 6.935 [95% confidence interval, 3.523-13.650]) to have an unnecessary peripheral intravenous catheter cannula in situ (Figure 1). With regard to the dressings of the 275 PVCs, 240 (87%) were intact and clean, and 35 (13%) were not. The majority of PVCs (242 [88%]) were in situ for 72 hours or less per hospital policy; 29 (11%) were in situ for more than 72 hours, and for 4 PVCs the duration could not be ascer-

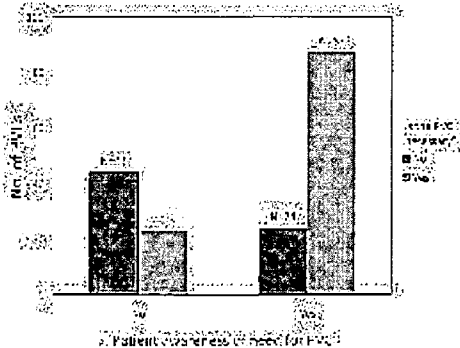


FIGURE 1. The relationship between the necessity for a peripheral venous catheter (PVC) and awareness of the indication for the PVC among 178 patients. Lack of awareness of the indication for the PVC was significantly associated with the patient having an unnecessary PVC in situ ($P < .001$).



Review

Intraoperative technique as a factor in the prevention of surgical site infection

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SUMMARY

Approximately five percent of patients who undergo surgery develop surgical site infections (SSIs) which are associated with an extra seven days as an inpatient and with increased postoperative mortality. The competence and technique of the surgeon is considered important in preventing SSI. We have reviewed the evidence on different aspects of surgical technique and its role in preventing SSI. The most recent guidelines from the National Institute for Health and Clinical Excellence in the UK recommend avoiding diathermy for skin incision even though this reduces incision time and blood loss, both associated with lower infection rates. Studies comparing different closure techniques, i.e. continuous versus interrupted sutures, have not found a statistically significant difference in the SSI rate, but using continuous sutures is quicker. For contaminated wounds, the surgical site should be left open for four days to allow for treatment of local infection before subsequent healing by primary intention. Surgical drains should be placed through separate incisions, closed suction drains are preferable to open drains, and all drains should be removed as soon as possible. There are relatively few large studies on the impact of surgical techniques on SSI rates. Larger, multicentre prospective studies are required to define what aspects of surgical technique impact on SSI, to better inform surgical practice and support education programmes for surgical trainees.

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Introduction

Surgical site infections (SSIs) account for 20% of healthcare-associated infections.¹ Approximately 5% of patients who undergo surgery develop SSI.² Patients with SSI are more likely to be admitted to the intensive care unit (ICU), remain in hospital approximately seven days longer, and have a significantly higher postoperative mortality.³ Thus SSI imposes severe demands on healthcare systems at a time when resources are particularly constrained.⁴

A number of procedure-related risk factors have been associated with SSI. These include long duration of procedure, wound classification, and absence of antibiotic prophylaxis. Length of stay before or after surgery is also a risk factor; inpatient stay for > 48 h before or for five days after the procedure increases the chances of SSI.^{5,6}

Aside from intraoperative technique, there are several standard approaches to prevent SSI. These include patient preparation, hand

antiseptics, appropriate antimicrobial prophylaxis before surgery, and postoperative surgical site care.⁷ Surgical attire is strictly regulated, as is the environment in the operating theatre.⁸ The bacterial counts in operating room air are directly proportional to the number of people moving about in the room.⁹ Early studies demonstrated a correlation between airborne bacteria and postoperative SSI in joint arthroplasty.^{10,11} However, a recent study queried the use of laminar air flow in operating theatres, reporting no reduction in SSI through its use.¹²

Most surgical teams have a strict view on surgical attire, changing into scrubs as well as wearing appropriate caps and masks. The number of people moving about in the operating room, although important, can be difficult to restrict given that many hospitals are also major referral centres with significant teaching commitments involving the presence of medical students in the operating theatre. Procedures and protocols in the operating theatre to minimise infection have recently been reviewed, but current practice is based on tradition and ritual, rather than on well-conducted trials.¹²

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Preventing infection in general surgery: improvements through education of surgeons by surgeons

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SUMMARY

Surgical patients are at particular risk of healthcare-associated infection (HCAI) due to the presence of a surgical site leading to surgical site infection (SSI), and because of the need for intravascular access resulting in catheter-related bloodstream infection (CRBSI). A two-year initiative commenced with an initial audit of surgical practice; this was used to inform the development of a targeted educational initiative by surgeons specifically for surgical trainees. Parameters assessed during the initial audit and a further audit after the educational initiative were related to intra- and postoperative aspects of the prevention of SSIs, as well as care of peripheral venous catheters (PVCs) in surgical patients. The proportion of prophylactic antibiotics administered prior to incision across 360 operations increased from 30.0% to 59.1% ($P < 0.001$). Surgical site dressings were observed in 234 patients, and a significant decrease was found in the percentage of dressings that were tampered with during the initial 48 h after surgery (16.5% vs 6.2%, $P = 0.030$). In total, 574 PVCs were assessed over the two-year period. Improvements were found in the proportion of unnecessary PVCs *in situ* (37.9% vs 24.4%, $P < 0.001$), PVCs *in situ* for > 72 h (10.6% vs 3.1%, $P < 0.001$) and PVCs covered with clean and intact dressings (87.3% vs 97.6%, $P < 0.001$). Significant improvements in surgical practice were established for the prevention of SSI and CRBSI through a focused educational programme developed by and for surgeons. Potentially, other specific measures may also be warranted to achieve further improvements in infection prevention in surgical practice.

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Introduction

The recent Hospital Infection Society Prevalence Survey found an overall prevalence of healthcare-associated infection (HCAI) in Irish hospitals of 4.9%, with this figure increasing to 6% in tertiary referral centres.¹ Surgical patients are at particular risk of HCAI due to the presence of a surgical site leading to surgical site infection

(SSI), the need for intravascular access resulting in catheter-related bloodstream infection (CRBSI), and suboptimal professional practice, specifically related to hand hygiene amongst surgeons and other healthcare professionals.

Approximately 5% of patients undergoing surgery develop an SSI.² SSIs are the second most common cause of HCAI.^{3,4} Patients who develop SSIs are up to 60% more likely to spend time in an intensive care unit, five times more likely to be re-admitted to hospital, and twice as likely to die compared with patients without an SSI.⁵ Standard procedures for the prevention of SSIs include pre-operative patient preparation, appropriate prophylactic antibiotics, careful and skilled surgical technique, intra-

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The role of topical antibiotics used as prophylaxis in surgical site infection prevention

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Compared with systemic antibiotic therapy, the topical or local delivery of an antibiotic has many potential advantages. However, local antibiotics at the surgical site have received very limited approval in any of the surgical prophylaxis consensus guidelines that we are aware of. A review of the literature was carried out through searches of peer-reviewed publications in PubMed in the English language over a 30 year period between January 1980 and May 2010. Both retrospective and prospective studies were included, as well as meta-analyses. With regard to defining 'topical' or 'local' antibiotic application, the application of an antibiotic solution to the surgical site intraoperatively or immediately post-operatively was included. A number of surgical procedures have been shown to significantly benefit from perioperative topical prophylaxis, e.g. joint arthroplasty, cataract surgery and, possibly, breast augmentation. In obese patients undergoing abdominal surgery, topical surgical prophylaxis is also proven to be beneficial. The selective use of topical antibiotics as surgical prophylaxis is justified for specific procedures, such as joint arthroplasty, cataract surgery and, possibly, breast augmentation. In selective cases, such as obese patients undergoing abdominal surgery, topical surgical prophylaxis is also proven to be beneficial. Apart from these specific indications, the evidence for use of topical antibiotics in surgery is lacking in conclusive randomized controlled trials.

Keywords: perioperative antibiotics, healthcare-associated infections, abdominal surgery, cardiothoracic, orthopaedic

Background

Surgical site infection (SSI) accounts for 20% of all healthcare-associated infections.¹ Approximately 5% of patients undergoing surgery develop SSI.² SSI results in failure of wound healing with subsequent increased treatment costs,³ a greater likelihood of admission to the intensive care unit, prolonged hospital stay and higher post-operative mortality.⁴ In particular, studies have demonstrated an extra 7–10 days inpatient stay in those with SSI.^{4–6} The associated hospital cost has been estimated at US\$3937 per infected patient.⁶ Therefore, there is interest in SSI and its prevention amongst surgeons and amongst many other healthcare professionals, because of the increased patient morbidity and the associated financial burden.

There are many interventions advocated to reduce SSI, including pre-operative assessment to optimize underlying disease such as diabetes mellitus, aseptic techniques in the operating theatre and the use of systemic prophylactic antibiotics.^{7–9} Amongst the many interventions advocated to prevent SSI, the effectiveness of pre-operative intravenous administration of antibiotic prophylaxis has been extensively studied and has been shown to be effective.^{10–15}

Surgical practice often includes the use of topical or local antimicrobial agents applied to the operative site to minimize

post-operative surgical infections, especially SSI. Compared with systemic antibiotic therapy, topical or local delivery of an antibiotic has many potential advantages, as well as some disadvantages, as outlined in a review by Lipsky and Hoey.¹⁶ The benefits of local application include high and sustained concentrations at the site of infection where local physiological changes may hinder the efficacy of systemic antibiotics.^{16–19} Other benefits include the limited potential for systemic absorption and toxicity, reduced volumes of antibiotic use, and, possibly, less potential for the development of antibiotic resistance (as there is likely to be less of an effect on, e.g. bowel flora).¹⁶ Novel agents that are not available systemically may also be used.¹⁶

While local hypersensitivity or contact dermatitis reactions and interference with local wound healing may be problematic, a major disadvantage of local antibiotics is that there are no specific efficacy criteria for agents in this setting that have been standardized and approved by any official oversight agency for evaluating their efficacy.¹⁶ Antibiotics may be delivered locally in the form of intraoperative washes or injections, locally applied lotions, solutions, powders, gels, creams or ointments, and antibiotic-impregnated beads or collagen implants. The more commonly used antibiotics include cephalosporins, aminoglycosides, glycopeptides, chloramphenicol and bacitracin. The pharmacodynamic/pharmacokinetic profiles vary depending