Lower-Extremity Function for Driving an Automobile After Operative Treatment of Ankle Fracture

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Background: The purpose of this study was to determine when patients recover the ability to safely operate the brakes of an automobile following operative repair of an ankle fracture.

Methods: A computerized driving simulator was developed and tested. Eleven healthy volunteers were tested once to establish normal mean values (Group I), and a group of thirty-one volunteers with a fracture of the right ankle were tested at six, nine, and twelve weeks following operative repair (Group II). The subjects were tested with a series of driving scenarios (city, suburban, and highway). Scores on the Short Form Musculoskeletal Assessment were recorded at six, nine, and twelve weeks and were compared with the results of the driving test. We investigated the effect of the time of the visit and of the testing condition on the braking times.

Results: The total braking time was 1079 msec for Group I and 1330, 1172, and 1160 msec for Group II at six, nine, and twelve weeks, respectively, postoperatively ($p = 0.0094$). The total braking time consistently improved for each of the driving scenarios at each successive data point ($p = 0.05$). The increase in the total braking time at six weeks meant an increase in the distance traveled by the automobile before braking of 22 ft (6.7 m) at 60 mph (96.6 km/hr), and the increase at nine weeks meant an increase of 8 ft (2.4 m) at 60 mph. The functional outcome improved at each successive visit, although no significant association was found between the functional scores and normalization of total braking time.

Conclusion: By nine weeks, the total braking time of patients who have undergone fixation of a displaced right ankle fracture returns to the normal, baseline value.

Driving an automobile requires a certain amount of lower-extremity strength and coordination as well as the ability to respond rapidly to emergency situations by switching the foot between the accelerator and brake pedals. Patients frequently ask when they can resume driving an automobile following a lower-extremity fracture. Currently, no guidelines are available to help the clinician or patient to ascertain the minimum functional ability needed to drive an automobile following a fracture of the ankle.

The effects of different forms of immobilization of ankle fractures on functional outcome and gait have been investigated in previous studies[1]. However, we are not aware of any published studies on the minimum functional ability required to safely operate an automobile following lower-extremity trauma. Several investigators have studied driving reaction times following common orthopaedic procedures such as knee arthroscopy, anterior cruciate ligament surgery, total hip replacement, and total knee replacement[2-6].

The purpose of this study was to determine when patients recover the ability to operate the foot controls of an automobile following operative repair of an ankle fracture.

Materials and Methods

A driving simulator consisting of actual brake and accelerator pedal assemblies attached to an automobile steering column was constructed. An automobile seat, adjustable for the patient's height, was utilized. A 14-in (35.6-cm) color monitor that displayed a driving simulation was placed in front of the steering wheel. The brake pedal was linked to a brake cylinder and force transducer, to provide the same feel and feedback as that of an actual automobile. To provide a most realistic feeling of resistance for the subjects, we removed the power brake booster from a 1997 Ford Probe automobile and a carburetor from a 1995 Chrysler LeBaron automobile and inserted them into the brake assembly. Both pedals were linked to the computer by means of an analog-to-digital acquisition device, which transmitted the positions of both pedals to the computer. LabVIEW software (National Instruments, Austin, Texas) was used to collect and display data by means of an analog/digital board (AT-EIO-64; National Instruments) with a sampling rate of 1000 Hz from the accelerator and brake pedals.

This project was approved by the institutional review board at the New York University-Hospital for Joint Diseases. Following attainment of informed consent, all subjects were tested on the driving simulator. Two groups of subjects were enrolled. First, healthy volunteers were tested once to establish the normal mean values for the variables tested (Group I). Inclusion criteria for this group included an age between twenty and seventy years, no systemic disease, no neurologic condition, possession of a valid driver's license, and no history of lower-extremity fracture or surgery. The second group of subjects (Group II) included a cohort of patients who had undergone operative fixation of a fracture of the right ankle, and they were tested at six, nine, and twelve weeks following the surgery. Prior to testing, these patients were non-weight-bearing and were performing active range-of-motion exercises. All patients began weight-bearing as tolerated at the time of the initial testing. Inclusion criteria for Group II included an age between twenty and seventy years, no systemic disease, no neurologic condition, possession of a valid driver's license, and previous operative treatment of an isolated malleolar fracture or a bimalleolar or trimalleolar ankle fracture within six weeks before the initial testing.

Subjects sat in the simulator and were allowed to adjust the seat to a comfortable driving position, which was then recorded and used for all follow-up tests. During the driving task, the computer displayed images of a speedometer, real-time relative values for the pedals, and specific target values. Subjects were asked to increase or decrease force on the pedal to match the target value. Three driving conditions (city, suburban, and highway) were simulated for each subject. The driving conditions differed in terms of the number of times that the subject was required to use the brake and how long he or she was supposed to maintain a specific speed. Each trial lasted about ninety seconds, and each subject performed a total of eighteen randomly assigned trials.

In the city condition, the average speeds ranged from 20 to 30 mph (32.2 to 48.3 km/hr), and subjects were required to apply the brake pedal five times during a ninety-second period. Of the three conditions, this one required the lowest average speed and the most frequent application of the brake pedal. In the suburban condition, the average speeds ranged from 30 to 40 mph (48.3 to 64.4 km/hr), and subjects were required to apply the brake pedal four times during a ninety-second trial. In the highway condition, the average speeds ranged from 40 to 60 mph (64.4 to 96.6 km/hr), and subjects were required to apply the brake pedal twice during a ninety-second trial.

Group-II patients were examined by an orthopaedist with use of the Short Form Musculoskeletal Assessment[7] (SFMA) prior to testing with the driving simulator.

The specific variables examined during the data acquisition included the initial reaction time (the time between the presentation of a stimulus to apply the brake and the moment that the subject initiated movement toward the brake pedal), foot movement time (the time between the initiation of movement toward the brake from the accelerator to the initial contact with the brake), brake reaction time (the time between the presentation of the stimulus and the initial contact with the brake), brake travel time (the time between the moment of initial contact with the brake and the moment that the brake pedal reached the end of its travel), and total braking time (the time between the initial stimulus and the moment that the brake reached the end of its travel) (Fig. 1). The initial reaction time was calculated by the computer in the following manner. The subject kept the simulator at a constant speed until a visual stimulus was presented to slow the speed. A decrease in the speed to a level 10% lower than the mean speed prior to the presentation of the stimulus was considered to be indicative of the subject's response to that stimulus. The time from the presentation of the stimulus to the 10% reduction in speed was termed the initial reaction time. The rest of the variables were directly extrapolated from the computer by means of the force transducers on the pedals. Each variable was tested six times for each of the three driving scenarios at each test date.

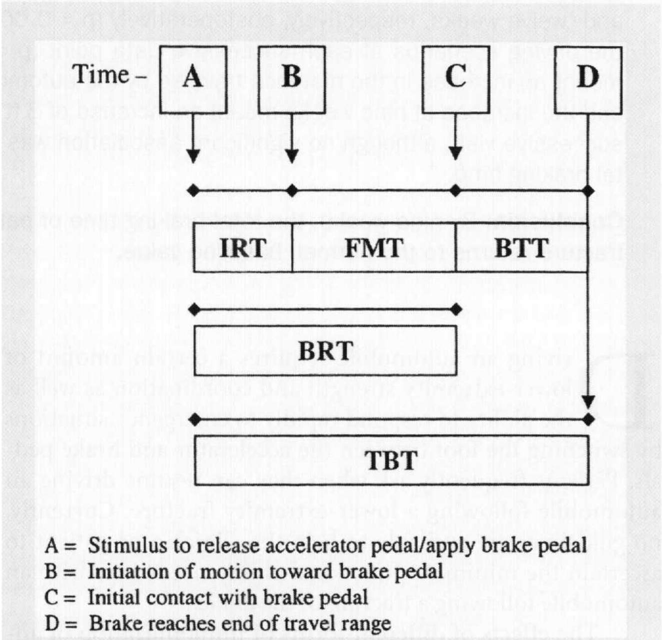

Fig. 1
Graphic description of the variables tested during the driving simulation. IRT = initial reaction time, FMT = foot movement time, BTT = brake travel time, BRT = brake reaction time, and TBT = total braking time.

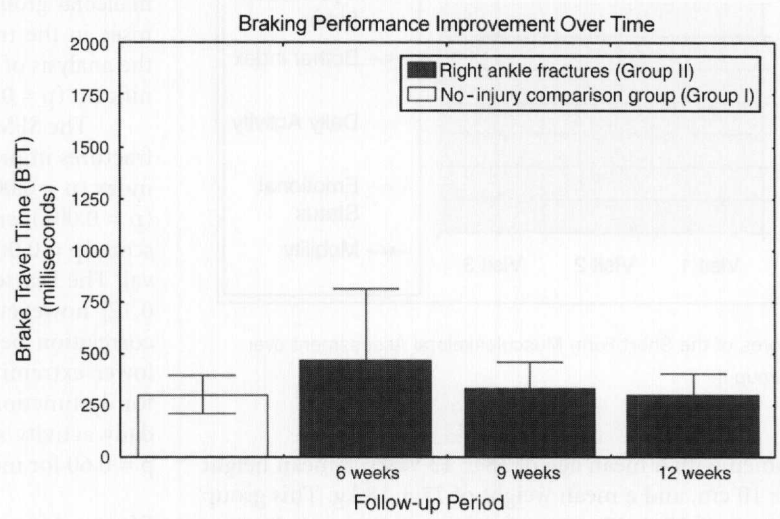

Fig. 2

Brake travel time according to the time of the visit.

All patients were treated in a similar manner following operative fixation of the fracture. At the time of the first follow-up, a functional brace was applied and the patient was allowed to perform free range-of-motion and isometric strengthening exercises. All patients remained non-weight-bearing on the right limb until the time of the initial testing, and then all were advanced to full weight-bearing.

Descriptive statistics (mean and standard deviation) of the demographic data and the results of the functional outcome measures were calculated. In addition, repeated analysis of variance was used to analyze the effect of the time from the surgery and of the testing condition on initial reaction time, foot movement time, brake travel time, brake reaction time, and total braking time. The Pearson correlation coefficient was utilized to compare the results of the functional outcome scores with the total braking time. A p value of ≤0.05 was considered significant.

Results

Eleven healthy volunteers (Group I) met the inclusion criteria. There were six men and five women with a mean age of 31 ± 9 years, a mean height of 177 ± 9 cm, and a mean weight of 79 ± 14 kg. This group had a mean 13 ± 9 years of driving experience. Thirty-one patients who had previously undergone open reduction and internal fixation of an ankle fracture formed Group II. There were eighteen men and thir-

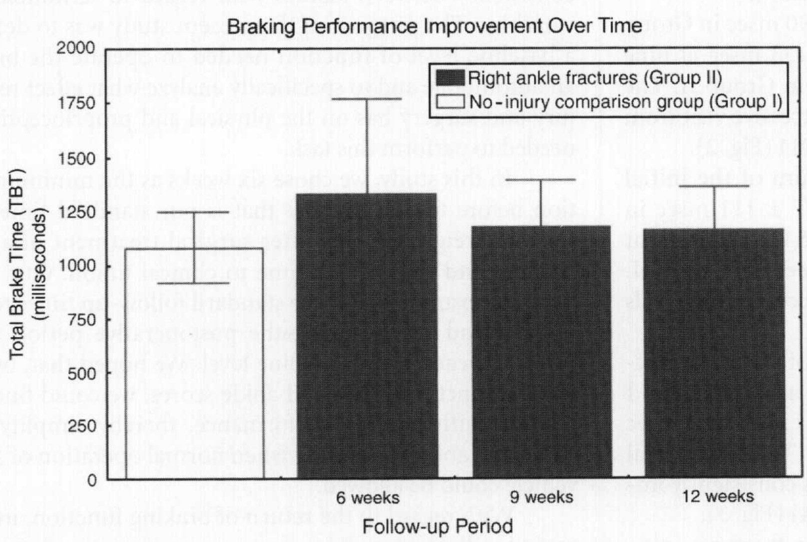

Fig. 3

Total braking time according to the time of the visit.

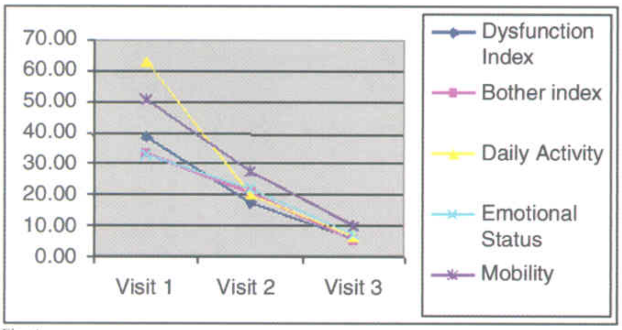

Fig. 4
Mean scores of the Short Form Musculoskeletal Assessment over time in Group II.

teen women with a mean age of 38 ± 13 years, a mean height of 171 ± 10 cm, and a mean weight of 77 ± 18 kg. This group had a mean of 17 ± 12 years of driving experience. No significant differences with regard to age (p = 0.135), height (p = 0.11), weight (p = 0.78), or years of driving experience (p = 0.27) were found between the two cohorts. Twenty-one of the thirty-one patients in Group II participated in the generation of all three data points. Ten patients missed one of the two tests following initial enrollment and were dropped from the final analysis. The analysis of variance took this into account.

The mean initial reaction time was 505 ± 80 msec in Group I, and 546 ± 87 msec at six weeks, 532 ± 81 msec at nine weeks, and 541 ± 104 msec at twelve weeks in Group II. When Group-II data were broken down into city, suburban, and highway scenarios, the initial reaction time under each condition was not improved at each successive test date (p = 0.69).

The mean foot movement time was 278 ± 54 msec in Group I, and 333 ± 82, 324 ± 59, and 330 ± 48 msec at six, nine, and twelve weeks, respectively, in Group II. Again, in Group II, the mean foot movement time for city, suburban, and highway driving did not improve at each test date (p = 0.37).

The mean brake travel time was 302 ± 90 msec in Group I, and 465 ± 346 msec at six weeks, 327 ± 133 msec at nine weeks, and 298 ± 106 msec at twelve weeks in Group II. The mean brake travel times improved at each successive visit from six to twelve weeks postoperatively (p = 0.0001) (Fig. 2).

The mean brake reaction time (the sum of the initial reaction and foot movement times) was 777 ± 111 msec in Group I and 870 ± 143 msec at six weeks, 854 ± 120 msec at nine weeks, and 870 ± 131 msec at twelve weeks in Group II. No improvement was seen at any of the successive intervals (p = 0.66).

The mean total braking time (the sum of the brake reaction and brake travel times) was 1079 ± 165 msec in Group I and 1330 ± 436 msec, 1172 ± 224 msec, and 1160 ± 203 msec at six, nine, and twelve weeks in Group II. The mean total braking time for each of the driving scenarios consistently improved at each successive test date (p = 0.0094) (Fig. 3).

There were fourteen isolated malleolar fractures, nine bimalleolar fractures, and eight trimalleolar fractures in Group II. The mean total braking time was 1181 msec in the isolated malleolar group, 1415 msec in the bimalleolar group, and 1298 msec in the trimalleolar group. With the numbers available, the analysis of variance showed these differences not to be significant (p = 0.17).

The SFMA scores for the patients with the treated ankle fractures improved over time (Fig. 4). The mean dysfunction index (p = 0.001), bother index (p = 0.02), daily activity score (p = 0.001), emotional status score (p = 0.003), and mobility score (p = 0.001) all improved at each successive testing interval. The Pearson correlation coefficient ranged from −0.08 to 0.12; however, with the numbers available, no significant correlation between the SFMA subscores and the return of lower-extremity driving function could be found (p = 0.79 for dysfunction index, p = 0.79 for bother index, p = 0.83 for daily activity score, p = 0.73 for emotional status score, and p = 0.60 for mobility score).

Discussion

Patients frequently ask when they may resume driving an automobile following lower-extremity surgery. There are certain medicolegal implications when a physician informs a patient that it is safe to drive. Physicians are often required by law to advise patients about a disability that may pose a relative danger to society. Furthermore, insurance companies can refuse coverage to motorists who drive against medical advice[5]. Driving an automobile safely requires a number of integrated cognitive, neurologic, and physical skills. Patients who sustain a lower-extremity fracture often rely on their physician for permission to return to normal daily activities. Little is known, however, about the minimum level of function needed in order to operate a motor vehicle safely. Previous investigators have reported on the driving performance of patients following common orthopaedic procedures[3-6,8]. However, those studies have been limited by the utilization of one data point, usually eight weeks postoperatively. Furthermore, there has been little consistency between studies with regard to terminology and variables. The purpose of the present study was to determine a baseline level of function needed to operate the brakes of an automobile and to specifically analyze what effect recent injury and surgery has on the physical and proprioceptive skills needed to perform this task.

In this study, we chose six weeks as the minimum duration before testing because that is our standard time-period for non-weight-bearing after surgical treatment of an ankle fracture and the average time to clinical union. Our test cohort was examined at three standard follow-up times to determine if and when during the postoperative period braking times returned to the baseline level. We hoped that, by determining functional foot and ankle scores, we could find a correlation with braking performance, thereby simplifying the clinician's ability to predict when normal operation of a motor vehicle could be allowed.

With regard to the return of braking function, improvement in all measured parameters was seen at each successive time interval under each of the driving conditions, as would be expected. The improvement in the initial reaction time at each successive test may represent a learning phenomenon, since this phase appears to be purely cognitive. The only independent parameter that improved by a significant margin at each successive test date was brake travel time, which was more than one and one-half times the control value at six weeks and had returned to the control value by twelve weeks. This finding may be the result of pain caused by the application of force by an injured ankle or possibly by some disconnect in the proprioceptive feedback loop.

Total braking time is the sum of all of the individual variables and is probably the best indicator of lower-extremity braking function. The total braking time of the normal controls was 1079 msec, whereas it was 1330 msec at six weeks for the patients who had sustained an ankle fracture. This difference of 251 msec translates into the automobile traveling an additional 22 ft (6.7 m) before braking, if the driving speed is 60 mph (96.6 km/hr), and 11 ft if the speed is 30 mph (48.3 km/hr). By nine weeks postoperatively, the difference in total braking time dropped to 93 msec, which translates into an increased distance before braking of only 8 ft (2.4 m) at a driving speed of 60 mph and of 4 ft (1.2 m) at 30 mph. Finally, at twelve weeks the difference in total braking time dropped to 81 msec, which translates into an increased distance before braking of 7 ft (2.1 m) at a driving speed of 60 mph and of 4 ft at 30 mph. While the delays in total braking time were significant, the change, from nine to twelve weeks, in the distance traveled before braking was too small to be of clinical relevance.

The SFMA scores showed functional improvement at each follow-up visit, but no correlation was found between those scores and the computer-generated data.

Limitations of this study include the fact that the driving simulator was not an actual vehicle. Some of the improvement seen in successive driving tests may represent some type of cognitive phenomenon, which cannot be distinguished from postoperative recovery. Also, the total braking time measured in this study is only one variable of many that may influence the ability of a patient to return to normal, safe driving.

On the basis of these data, we concluded that driving performance with regard to lower-extremity braking function is impaired at six weeks following surgical repair of a right-sided ankle fracture. Normal braking function appears to return by nine weeks. No significant further improvement in braking function is seen between nine and twelve weeks. The increased time needed to brake an automobile during the first six weeks after operative repair of a right-sided ankle fracture may have implications with regard to the best time for such patients to resume driving. ■

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