Driving After Orthopaedic Surgery

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Abstract

The decision to drive after orthopaedic injury or surgery is fraught with legal and safety issues. Although driving is an important part of most patients' lives, there are no well-established guidelines for determining when it is safe to drive after injury or treatment. Typically, impairment in driving ability is measured by changes in the time needed to perform an emergency stop. Braking function returns to normal 4 weeks after knee arthroscopy, 9 weeks after surgical management of ankle fracture, and 6 weeks after the initiation of weight bearing following major lower extremity fracture. Patients may safely drive 4 to 6 weeks after right total hip arthroplasty or total knee arthroplasty. Patients should not drive with a cast or brace on the right leg. Upper extremity immobilization may cause significant impairment if the elbow is immobilized; however, simple forearm casts may be permissible.

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The decision to resume driving after orthopaedic injury or surgery merits important legal and safety considerations. The inability to drive presents a significant obstacle for patients.[1] Patients commonly drive without consulting a physician,[1] while still on narcotics,[1] and while wearing upper extremity splints or casts.[2] Despite the importance to patients of driving, no well-established guidelines exist to help either the patient or the physician determine when it is safe for the patient to return to driving.

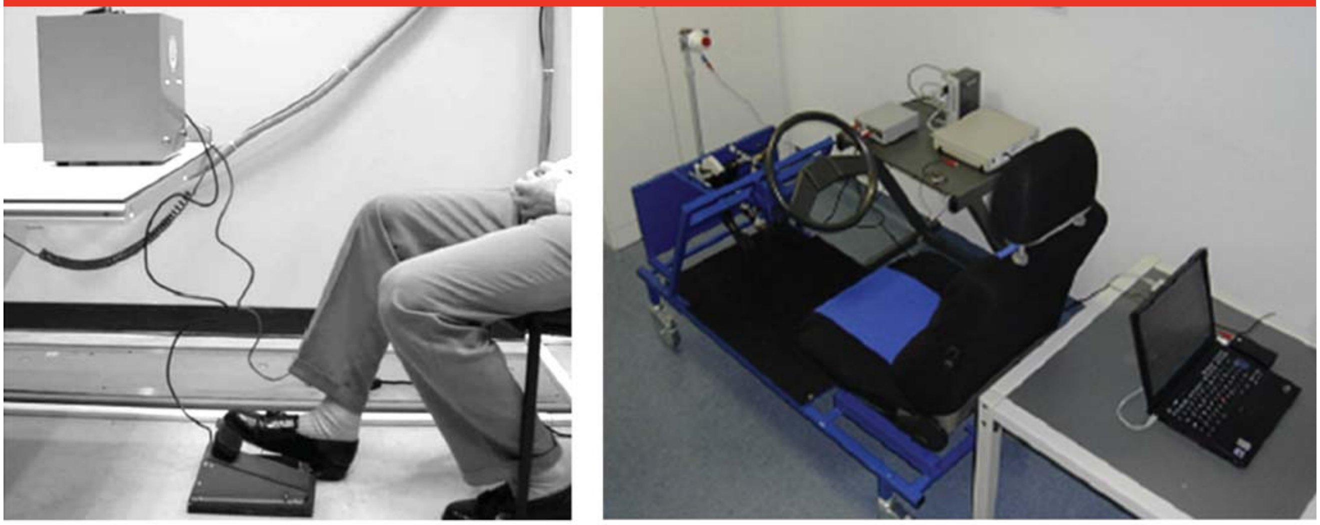
Common Testing Setup and Definitions

The ability to stop in an emergency is critical to safe driving. Thus, most studies focus on braking function after surgery or during immobilization. Driving simulators can be used to evaluate braking ability (Figure 1). Because most vehicles are automatic transmission, most studies assess patients with right-sided surgery. To date, no study has used a simulator with manual transmission. Although the pedal configuration is the same worldwide, the side on which the driver sits and the side of the road on which the vehicle is driven varies by country. Thus, studies may differ by country with respect to right- versus left-sided outcomes.

Braking ability is commonly reported in terms of braking reaction time (BRT) and total braking time (TBT). Nomenclature and definitions vary between studies. Braking reaction time is also known as driver reaction time.[3] Reaction time may be called initial reaction time,[4,5] thinking time,[6] or gas-off time.[7] Movement time is also referred to as transition time[7] and foot movement time.[4,5] The terms brake travel time (BTT) and braking time are standard.

BRT is the time from the appearance of a stimulus until contact is made with the brake pedal (Figure 2). Different studies have defined this as the time to

Figure 1



A B

Photographs of common driving simulator setups. **A,** The American Automobile Association automatic brake reaction timer model 3548, which includes a light console and accelerator/brake pedal combination. **B,** Car simulator connected to a computer. (Panel A reproduced with permission from Pierson JL, Earles DR, Wood K: Brake response time after total knee arthroplasty: When is it safe for patients to drive? *J Arthroplasty* 2003;18[7]:840-843. Panel B reproduced with permission from Marques CJ, Barreiros J, Cabri J, Carita AI, Friesecke C, Loehr JF: Does the brake response time of the right leg change after left total knee arthroplasty? A prospective study. *Knee* 2008;15[4]:295-298.)

Figure 2

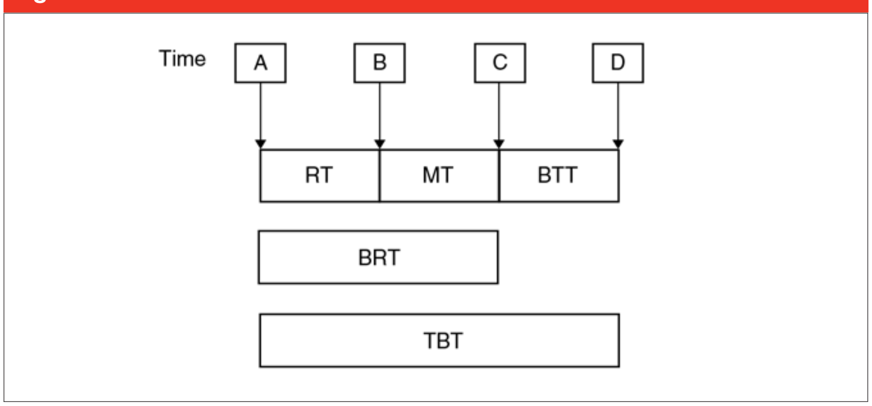


Illustration of commonly tested braking parameters. A = appearance of stimulus to begin braking, B = initiation of movement from accelerator to brake, BRT = brake reaction time, BTT = brake travel time, C = initial contact with brake pedal, D = brake reaches the end of travel, MT = movement time, RT = reaction time, TBT = total braking time. (Adapted with permission from Egol KA, Sheikhazadeh A, Mogatederi S, Barnett A, Koval KJ: Lower-extremity function for driving an automobile after operative treatment of ankle fracture. *J Bone Joint Surg Am* 2003;85[7]:1185-1189.)

initial brake contact,[7-10] the time to fully depress the brake pedal,[4,5,11-14] and otherwise based on the amount of force applied.[3,6,15-25] Reaction time (RT) begins with the appearance of a stimulus and ends on initiation of movement from the accelerator. Movement time (MT) begins after RT and ends with initial contact with the brake. BRT is the sum of RT and MT. Some studies measure BTT, which is the time from initial contact with the brake until it reaches its end point. TBT is the sum of BRT and BTT. Some studies use TBT and BRT interchangeably, and careful attention should be paid to definitions. No standardized BRT threshold for safe driving exists, but thresholds for four countries are noted in Table 1. Multiple factors may affect BRT, including driver age, sex, level of fatigue, use of alcohol and drugs, task complexity, and environmental factors such as ambient light level and traffic and brake lights.[3,8,9]

Evaluating a Patient for Fitness to Drive

There are no published guidelines for determining a patient's fitness to drive.

Table 1

Braking Reaction Time Thresholds by Country

Country	Institution	Threshold (msec)
United States	Federal Highway Administration	700[26]
United Kingdom	Department for Transport	700[27]
Australia	Royal Automobile Club of Victoria	750[28]
Germany	German Commission on Reaction Times	1,500[29]

Physicians commonly permit driving when the patient is no longer immobilized, has resumed full weight bearing, or has full grip strength.[1,30,31] Patients also may be asked to perform practice drives, cease narcotic use, or obtain clearance from a physical therapist.[1]

Objective measures of driving ability are difficult to obtain because driving simulators are rare in the clinical setting. Accordingly, physicians have used other methods to assess patients' ability to drive safely. The step test, in which a seated patient steps over a small box for 10 seconds, and the stand test, in which a patient rises from a seated position as many times as possible in 10 seconds, are correlated with BRT following knee arthroscopy,[17] anterior cruciate ligament (ACL) reconstruction,[20] and first metatarsal osteotomy.[12] The Short Musculoskeletal Function Assessment and its components are not correlated with BRT after surgically treated ankle fracture or major lower extremity trauma.[4,5] Disagreement exists about the use of the visual analog scale for patients with lumbar radiculopathy.[3,25] Although further evidence is needed before the step and stand tests are more widely applied, they can be useful when determining fitness to drive.

Medicolegal Implications

Studies indicate that orthopaedic surgeons have poor knowledge of the law regarding driving after surgery.[31-33] Nevertheless, many physicians offer advice to patients about driving.[32] Although official guidelines are of interest to some surgeons,[31] surgeons may not use the available evidence when counseling patients. In one survey, surgeons were found to permit driving at a mean of 7 weeks after surgically treated ankle fracture,[1] even though a study published 5 years earlier concluded that it took 9 weeks to brake safely after that injury.[5]

Insurance companies are reluctant to determine a patient's fitness to drive and generally place the responsibility on the patient.[32-36] Some may defer to the physician's judgment if a specific clearance is given.[32,34] In general, law enforcement agencies determine what constitutes impaired driving on a case-by-case basis and they, too, place responsibility for the decision to drive on the patient.[33,35,36]

By clearing a patient to drive, the physician is exposed to liability for injuries incurred by the patient and others involved in accidents with the patient.[1] Although published studies provide a framework for decision-making, individualized approaches and patients' awareness of their own responsibility will optimize safe return to driving.

Upper Extremity

Upper extremity splints, casts, and slings are commonly used in orthopaedics. Even though the use of both arms is essential to the safe operation of a vehicle, no study has evaluated driving ability after upper extremity injury or surgery. Several studies, however, have attempted to define the effects of upper extremity immobilization on the ability to drive. Patients have conflicting opinions about their ability to drive in simple forearm casts, but they feel unsafe with immobilization of a more proximal joint or the wrist and digits together.[36,37]

Drivers' perceptions of impairment caused by immobilization may be underestimated. One study asked a driver to self-evaluate the limitations imposed by three below-elbow casts—simple forearm, thumb spica, and Bennett—while driving a manual transmission vehicle.[38] The left arm thumb spica and Bennett cast caused marked impairment. No impairment was noted with a right forearm cast. In a similar study conducted in Australia, an occupational therapist and a driving instructor evaluated the author while he drove in below-elbow and above-elbow casts.[2] The driving instructor failed the driver in all testing conditions. However, the occupational therapist gave the driver a passing grade when the driver wore below-elbow casts. The authors attributed this outcome to single-arm driving and other compensatory maneuvers, which may not be possible in either elderly or impaired patients. They concluded that driving was unsafe with any upper extremity cast. These discrepancies suggest that self-assessment of driving ability may be difficult.

The effect of upper extremity splints may depend on driving skill. In one study, police recruits wore above-elbow thumb spica and below-elbow splints while driving on a timed course.[39] The recruits completed various tasks driving in both forward and reverse. The drivers ex-

Table 2

Driving Simulator Studies of Braking Time With Right Lower Extremity Immobilization

Study	Intervention	No. of Participants	Comparison	Outcome	Increase in Stopping Distance at 60 MPH	Conclusions
Tremblay et al[23]	RLE immobilization	48	Athletic shoe	BRT[a]	0.9 ft with AirCast Walker (DJO)	Impact of immobilization is unclear
Orr et al[14]	RLE immobilization	35	Athletic shoe	BRT[b]	6.1 ft with BKC, 9.2 ft with CAM, 6 ft with LFA	No driving with LFA, BKC, or CAM
Waton et al[6]	RLE immobilization	23	Unrestricted leg	TBT[c]	18.4 ft with AKC, 12.5 ft with BKC, 9.2 ft with knee immobilizer at 0°	Increasing immobilization leads to increased braking time

AKC = above-knee cast, BKC = below-knee cast, BRT = braking reaction time, CAM = controlled ankle motion orthosis, LFA = left foot driving adaptor, MPH = miles per hour, RLE = right lower extremity, TBT = total braking time

[a] End point: 200 N of pressure.

[b] End point: fully depressed brake pedal.

[c] End point: 100 N of pressure.

perienced statistically significant slowing while wearing either splint on the left arm, but the slowing was not significant when a splint was worn on the right arm. The authors suggested that driving in reverse contributed to the slower times with left-arm immobilization.

Simulators have been used to assess the effects of upper extremity immobilization. In one British study, eight healthy volunteers operated a driving simulator while alternately wearing a below-elbow cast on each arm.[40] Patients wearing right-arm casts drove more cautiously under routine conditions and had worse responses to various hazards. Drivers wearing left-arm casts experienced less deterioration in their driving ability. In an American study, healthy volunteers were asked to avoid hazards in a simulated driving course with and without their dominant arm immobilized in a sling.[41] Drivers wearing a shoulder sling were involved in significantly more crashes ($P < 0.01$); parameters such as lane position, distance from the hazard, or the maximum steering angle were the same with and without the sling.

Even in healthy volunteers, immobilization of either arm in a splint or sling significantly impairs driving ability. Patients wearing slings, above-elbow splints, or left below-elbow splints should be cautioned against driving. Conflicting recommendations in North America about driving in a right below-elbow splint may lead surgeons to consider allowing select patients to drive while wearing a splint.

Lower Extremity

Understandably, evaluation of driving after lower extremity surgery or immobilization has focused on patients with right-side pathology. Although most drivers use the right foot for the accelerator and brake, some use a two-footed driving technique, in which the left foot is used to brake. Some studies specifically accommodated this variability, which makes the interpretation of results and comparison between studies difficult.[21] In a study of amputees who had been fitted with prostheses, a two-footed driving technique was found to result in slower BRT than any other pattern of accelerator and brake usage.[11] This technique likely should be avoided in patients with other types of lower extremity injury, as well.

Immobilization

Lower extremity immobilization restricts motion and proprioception in the affected limb. In one study, a police officer and a physician were tested on a driving course while wearing below-knee casts (BKCs).[42] They were evaluated by a police officer with advanced driving training. Only the use of a left BKC in an automatic transmission vehicle was considered safe. Use of a cast shoe did not affect driving performance.

To quantify the effect of immobilization on driving ability, several studies used simulators to test braking function (Table 2). In 48 healthy volunteers, maximum braking force was significantly lower when wearing a BKC than when wearing an AirCast Walker (DJO) or an athletic shoe ($P < 0.0001$).[23] However, all groups well-exceeded the pressure required for braking. BRT and TBT were fastest with the athletic shoe. Under distracted conditions, BRT and TBT were slower with the orthosis than with the cast.

Table 3

Driving Simulator Studies of Braking Time Following Right Ankle Fracture and Major Extremity Trauma

Study	Injury	No. of Patients	No. of Healthy Volunteers	Outcome	Increase in Stopping Distance at 60 MPH	Conclusions
Egol et al[5]	Surgically managed right ankle fracture	31	11	TBT[a]	22 ft at 6 wk, 8 ft at 9 wk, 7 ft at 12 wk	Safe to drive 9 wk after surgery
Kane et al[16]	Right ankle fracture	7 surgically treated, 18 nonsurgically treated	NR	BRT[b]	NR	Surgical group: after cast removal, wait 4 wk before driving. Nonsurgical group: after cast removal, wait 2 wk before driving.
Egol et al[4]	Major lower extremity trauma	11 with long bone fracture, 22 with articular fracture	12	BTT[c]	Long bone fracture: 9.9 ft at 6 wk, 3.6 ft at 9 wk, 3.3 ft at 12 wk. Articular fracture: 12.5 ft at 12 wk, 6.6 ft at 15 wk, 5.2 ft at 18 wk	Safe to drive 6 wk after initiation of weight bearing

BRT = braking reaction time, BTT = brake travel time, MPH = miles per hour, NR = not reported, TBT = total braking time
[a] End point: fully depressed brake pedal.
[b] End point: 100 N of pressure.
[c] End point: initial contact with brake pedal.

A similar study tested 35 volunteers on a driving simulator while wearing a BKC or a controlled ankle motion orthosis, and while using a left-foot driving adaptor.[14] All experimental groups had slower TBT than the control group. The authors concluded that it was unsafe to drive with either right ankle immobilization or a left-foot driving adaptor.

Only one study has evaluated the effect of knee immobilization on driving.[6] Twenty-three volunteers were tested wearing an above-knee cast (AKC), a BKC, and a hinged knee brace limited to varying degrees of flexion. Wearing the AKC, BKC, and hinged brace fixed at zero degrees resulted in slower TBT compared with unrestricted driving. Additionally, the AKC was associated with slower TBT than in all hinged knee brace groups. An association was noted between increasing levels of restriction and increased braking time.

Although adequate braking force can be generated even with immobilization of the right lower extremity, delays in BRT result in unsafe stopping distances with such immobilization, particularly at the knee. Automatic transmission vehicles can be operated safely despite left lower extremity immobilization. Left-foot driving adapters result in impairment similar to that with a BKC or an orthosis on the right leg.

Fracture

Deciding when to drive after a fracture is difficult. Some patients have multiple injuries, and rates of healing and recovery vary by patient. Furthermore, fracture severity varies markedly within any classifiable type (eg, tibial plateau). Surgeons have difficulty determining which patients are fit to drive. A survey of British surgeons found consensus in only 61% of scenarios involving lower extremity fractures and in 43% of scenarios involving upper extremity fractures.[30] Full weight bearing in the lower extremity is a commonly cited criterion for fitness to drive.[1,30,31] Other criteria include walking without crutches, clinical and radiologic findings, and patient self-assessment that he or she can drive safely.

Two studies have used simulators to evaluate BRT after ankle fracture (Table 3). In one study, 7 patients with surgically managed right ankle fractures and 18 patients with nonsurgically managed right ankle fractures were tested at the time of cast removal and at subsequent 2-week intervals.[16] In the nonsurgical group, BRT was slower than that of control subjects at the time of cast removal but not thereafter. In surgically treated patients, BRT was slower at the time of cast removal and 2 weeks after cast removal but not thereafter. Duration of casting and BRT values were not reported.

Egol et al[5] evaluated 31 patients with surgically treated right ankle fractures and 11 healthy control subjects. Patients were tested at 6, 9, and 12 weeks after surgery under city, suburban, and highway driving conditions. Mean BTT and TBT improved significantly at each testing point ($P = 0.0001$ and $P = 0.0094$, respectively), but the authors did not report whether they differed from control subjects. There was no difference in TBT for patients with isolated malleolar, bimalleolar, and trimalleolar ankle fractures ($P = 0.17$). Those authors concluded that TBT had improved sufficiently by 9 weeks postoperatively to permit safe vehicle operation.

In a later study, Egol et al[4] evaluated patients with major right lower extremity trauma. Eleven patients with long bone fractures and 22 patients with articular fracture (ie, acetabulum, tibial plateau, tibial plafond, calcaneus) were tested at all three time points. Testing began with weight bearing at 6 weeks in the long bone fracture group and at 12 weeks in the articular fracture group, with additional testing at 3-week intervals thereafter, up to 12 weeks and 18 weeks, respectively. Both groups showed significant improvement in BTT from the first to the third test ($P = 0.05$) but not between the second and the third test. The authors concluded that BTT improved satisfactorily 6 weeks after the initiation of weight bearing (12 and 18 weeks postoperatively for the long bone and articular groups, respectively). The acceptable value for change in stopping distance varied between studies (8 versus 3.3 feet at 60 miles per hour).[4,5] With the less stringent cutoff, the two patient groups reached acceptable stopping distances of 3.6 and 6.6 feet by 9 and 15 weeks, respectively.

Although the decision to drive after a fracture is a challenging one, a few guidelines are available to help the surgeon. Most surgeons agree that full weight bearing is essential to driving clearance. Acceptable braking function is achieved 2 weeks after cast removal for nonsurgically managed ankle fracture, 9 weeks after surgery for ankle fracture, and 18 weeks after surgery for an articular fracture. Although one study suggested waiting 12 weeks after surgery in patients with long bone fractures, 9 weeks appears sufficient to achieve acceptable braking function after this injury.

Total Hip Arthroplasty

Driving after total hip arthroplasty (THA) is complicated by the nature of the surgery and the rehabilitation process. Depending on surgical approach, patients are instructed to avoid positions of flexion and adduction (eg, sitting in a car) to minimize the risk of dislocation. Patients may report subjective improvement in their ability to drive after surgery, and most feel comfortable to drive by 6 to 8 weeks postoperatively.[43]

In one of the earliest simulator studies, MacDonald and Owen[19] tested 25 patients before and after THA. Based on previous recommendations of an 8-week driving hiatus, patients were evaluated preoperatively and at 8 and 32 weeks postoperatively. Mean BRT improved significantly at 8 weeks and again at 32 weeks postoperatively ($P = 0.05$). Mean BRT was significantly slower following right THA than either following left THA or in control subjects ($P < 0.05$). In a small group of patients, BRT remained increased 12 weeks from surgery. The authors of the study could not identify any predictive factors for this outcome.

In a larger study, 90 patients who underwent right or left THA were tested preoperatively and at 1 week, 4 to 6 weeks, 26 weeks, and 52 weeks postoperatively.[10] Overall mean BRT was slower at 1 week postoperatively, which was attributable to the results of the patients who underwent right THA. Mean BRT remained unchanged in patients who underwent left THA. Beginning at 4 to 6 weeks after surgery, BRT improved compared with preoperative values. Significant improvement was seen up to 1 year after surgery ($P < 0.001$). Based on the available data, patients may resume driving 4 to 6 weeks after right THA (Table 4). Although it is possible to safely brake 1 week after left THA, patients should not drive unless they can maintain hip precautions when indicated.

Total Knee Arthroplasty

Total knee arthroplasty (TKA) is the best-studied orthopaedic procedure with respect to braking function (Table 4). Spalding et al[22] measured BRT in 29 patients undergoing TKA and in 20 healthy control subjects. The surgical patients were evaluated preoperatively and at 4, 6, 8, and 10 weeks postoperatively. Drivers who underwent right TKA demonstrated slower BRT at 4 and 6 weeks postoperatively but returned to baseline at 8 weeks postoperatively. Patients who underwent left TKA had no change in BRT throughout the study. In another study, 31 patients who underwent TKA were tested preoperatively and at 3, 6, and 9 weeks postoperatively.[21] Thirteen patients had bilateral TKA, 12 had right TKA, and 6 had left TKA. At 3 weeks postoperatively, BRT was slightly slower compared with the preoperative measurement, but it improved significantly by 6 and 9 weeks after surgery ($P = 0.03$ and $P = 0.006$, respectively).

More recent studies have found earlier return of braking function. In one study, 21 patients who under-

Table 4

Driving Simulator Studies of Braking Time Following Total Hip Arthroplasty and Total Knee Arthroplasty

Study	Intervention	No. of Patients	Comparison	Outcome	Increase in Stopping Distance at 60 MPH	Conclusions
MacDonald and Owen[19]	THA	22	15 healthy volunteers	BRT[a]	None	Safe to drive 8 wk after right THA
Ganz et al[10]	THA	90	Preoperative measurement	BRT[b]	2.6 ft at 1 wk	Safe to drive 4–6 wk after right THA and, if patient can maintain hip precautions, 1 wk after left THA
Spalding et al[22]	TKA	29	Preoperative measurement, 20 healthy volunteers	BRT[a]	NR	Safe to drive 8 wk after TKA
Pierson et al[21]	TKA	31	Preoperative measurement	BRT[c]	NR	Safe to drive 6 wk after TKA
Marques et al[9]	TKA	21	Preoperative measurement	BRT[b]	3.3 ft at 10 d, 0.6 ft at 30 d	Safe to drive 30 d after TKA
Marques et al[8]	TKA	24	Preoperative measurement	BRT[b]	None	Safe to drive 10 d after left TKA
Liebensteiner et al[18]	TKA	31	Preoperative measurement, 31 healthy volunteers	BRT[c]	0.9 ft at 2 wk	No restriction >2 wk
Dalury et al[7]	TKA	29	Preoperative measurement	BRT[b]	3.5 ft at 4 wk	Safe to drive 4 wk after TKA

BRT = braking reaction time, MPH = miles per hour, NR = not reported, THA = total hip arthroplasty, TKA = total knee arthroplasty
[a] End point: 100 N of pressure.
[b] End point: initial contact with brake pedal.
[c] Unspecified end point.

went right TKA performed simple and complex braking tasks preoperatively and at 10 and 30 days postoperatively.[9] At 10 days, BRT increased significantly ($P = 0.04$) due to an increase in MT, but it returned to baseline by 30 days after surgery. Similar results were found for the complex braking tasks, with slightly longer BRT. Another study tested 29 right TKA patients preoperatively and beginning at 4 weeks after surgery.[7] Tests continued at 2-week intervals until the patients achieved a BRT at least as fast as that of the preoperative test. All patients passed at the first test, with a significantly faster mean BRT ($P = 0.002$). Liebensteiner et al[18] evaluated 31 TKA patients preoperatively and at 2 and 8 weeks postoperatively. Neither right- nor left-sided TKA patients had a significant increase in BRT at the 2-week evaluation. There was a significant decrease in BRT by 8 weeks for both groups (right, $P = 0.001$; left, $P = 0.003$). Although the proportion of patients with BRT >700 msec at 2 weeks was increased, this improved by 8 weeks and was not significant at any time point. Twenty patients who were excluded for not completing the 8-week evaluation did have significant increases in BRT at the 2-week evaluation (right, 669 to 696 msec; $P = 0.022$) (left, 658 to 690 msec; $P = 0.028$). The authors did not report on the combined effect of these two patient groups.

Only one study has specifically addressed the effect of left TKA on right leg BRT.[8] Twenty-four patients were tested on a driving simulator preoperatively and again 10 days postoperatively. By 10 days after surgery, there was no difference in BRT compared with preoperative values. The authors concluded that left TKA has no effect on BRT provided the patient drives an automatic transmission.

After right TKA, braking function returns to baseline by 4 weeks after surgery. One study indicated that patients may safely drive as early as 2 weeks after surgery; however, due to significant attrition in that study, 4 weeks is a more prudent goal. Braking function does not change after left TKA, and patients may consider driving by 10 days after surgery.

Knee Arthroscopy and ACL Reconstruction

Arthroscopic knee surgery and ACL reconstruction are common orthopaedic procedures. However, only one study has evaluated braking function after knee arthroscopy.[17] Thirty patients who underwent various arthroscopic procedures, including meniscectomy and chondroplasty, were compared with 25 control subjects. Compared with preoperative measurements, patients had significantly slower BRT 1 week after surgery ($P = 0.03$) but showed significant improvement by 4 weeks postoperatively ($P = 0.02$). The control group had significantly faster BRT at each time point ($P = 0.03$, $P = 0.001$, and $P = 0.008$, respectively). The type of surgery performed had no effect on the changes in BRT. Even 4 weeks after surgery, 30% of the patients had not returned to their preoperative BRT values, and the authors recommended the step test and/or the stand test to determine fitness to drive. In a prospective study of 100 patients who underwent knee arthroscopy, surgeons advised patients to refrain from driving for 2 days to 4 weeks; this indicates that surgeon practice largely reflects the literature.[44]

Two studies have evaluated driving after ACL reconstruction. In one study, 14 patients were evaluated at 2-week intervals for 10 weeks after surgery.[24] Twenty-one control subjects were evaluated, as well. Men and women were evaluated separately and their results compared with published normative data for BRT. Men demonstrated significant improvement in BRT until week 6 and from week 8 to week 10. Women had a gradual continued improvement in BRT, but week-to-week differences were not significant. Both men and women outperformed controls beginning in week 6. In the other study, 31 patients who had undergone ACL reconstruction (16 right, 15 left) were evaluated preoperatively and at 2, 4, 6, and 8 weeks after surgery.[20] Nine control subjects were also evaluated. By 2 weeks postoperatively, BRT was similar between patients with left ACL repair and the control subjects. Patients who underwent right ACL reconstruction had significantly slower BRT than controls until week 6, although nearly 25% of subjects still had not equaled their preoperative BRT.

Patients may anticipate a quick recovery after arthroscopic knee surgery; however, braking function does not return until 4 weeks after arthroscopy and 6 weeks after right ACL reconstruction. Following left ACL reconstruction, patients may drive as early as 2 weeks after surgery. However, there is significant variability between patients; the step and stand tests may help guide decision-making. The available literature is summarized in Table 5.

Foot and Ankle

Foot pain may impair braking function after foot or ankle surgery. Patients also risk damaging their surgical reconstruction if bone or soft tissues have not adequately healed prior to resumption of driving. Two studies have evaluated driving after foot and ankle surgery (Table 5). Holt et al[12] tested 28 patients who underwent 1st metatarsal osteotomy for hallux valgus correction preoperatively, as well as at 2 and 6 weeks postoperatively. Twenty-eight control subjects were tested for comparison. At 2 weeks after surgery, only seven patients were able to complete testing, and they recorded slower BRT than at their preoperative tests. At 6 weeks, BRT was significantly improved relative to preoperative values ($P = 0.047$) but remained slower than that of the control subjects.

One study evaluated changes in braking function after right ankle arthrodesis. Ten patients with a successful tibiotalar arthrodesis were compared with 10 age-matched controls.[13] The length of time between surgery and testing was not reported. BRT was measured using a simulator, and pedobarographic measurements were obtained using an in-shoe monitor. BRT was significantly slower following arthrodesis ($P = 0.03$). Control subjects used both the forefoot and midfoot to brake, but surgical patients applied braking pressure with the forefoot only. The authors attributed the slower BRT following arthrodesis to the lack of ankle dorsiflexion and resultant use of hip and knee motion to clear the pedals. Although BRT was slower postoperatively, it was within acceptable limits, so the authors indicated that such patients were safe to drive.

Spine

Preexisting or acquired neurologic deficits and pain make the decision to drive after spine surgery particularly challenging. Patients with preoperative deficits may have been unable to drive, or they may have continued to drive despite their impairments. In addition, many patients with spinal pathology may have been taking pain medications for some time before surgery and may require an orthosis in the postoperative period.

Lumbar Radiculopathy

Two studies have evaluated BRT in patients with lumbar radiculopathy (Table 6). In both studies, mean patient BRT was significantly slower than in controls at all time points.[3,25]

Table 5

Driving Simulator Studies of Braking Time Following Lower Extremity Procedures

Study	Intervention	No. of Patients	Comparison	Outcome	Increase in Stopping Distance at 60 MPH	Conclusions
Hau et al[17]	Knee arthroscopy	30	25 control subjects	BRT[a]	16.2 ft at 1 wk	Safe to drive 4 wk after surgery
Nguyen et al[20]	ACL reconstruction	31	25 control subjects	BRT[a]	67.3 ft at 4 wk	Safe to drive 6 wk after right ACL surgery. No change after left ACL surgery.
Gotlin et al[24]	ACL reconstruction	14	21 control subjects	BRT[b]	NR	Safe to drive 6 wk after surgery
Holt et al[12]	1st metatarsal osteotomy	28	Preoperative measurement, 28 control subjects	BRT[c]	3.9 ft at 2 wk	Safe to drive 6 wk after surgery
Jeng et al[13]	Right ankle arthrodesis	10	10 control subjects	BRT[c]	NR	BRT slower, but within acceptable limits

ACL = anterior cruciate ligament, BRT = braking reaction time, MPH = miles per hour, NR = not reported
[a] End point: 200 N of pressure.
[b] Unspecified end point.
[c] End point: fully depressed brake pedal.

Table 6

Driving Simulator Studies of Braking Time Related to Spine Surgery

Study	Intervention	No. of Patients	Comparison	Outcome	Increase in Stopping Distance at 60 MPH	Conclusions
Al-khayer et al[3]	SNRB to manage radiculopathy	10 right, 10 left	Preoperative measurement, 20 age- and sex-matched control subjects	BRT[a]	8 ft at 0 wk, 3 ft at 2 wk, 1.7 ft at 6 wk	SNRB has an unclear effect on fitness to drive
Thaler et al[25]	Diskectomy to manage radiculopathy	23 right, 23 left	Preoperative measurement, 31 control subjects	BRT[b]	None	Safe to drive after discharge from the hospital
Liebensteiner et al[15]	Lumbar spinal fusion	21	Preoperative measurement, 31 control subjects	BRT[b]	3.8 ft before discharge	Safe to drive after discharge from the hospital

BRT = braking reaction time, MPH = miles per hour, SNRB = selective nerve root block
[a] End point: 200 N of pressure.
[b] Unspecified end point.

One study involved 20 patients undergoing selective nerve root block (SNRB) for radiculopathy (10 right, 10 left).[3] Immediately following SNRB, BRT was significantly increased (right, $P < 0.005$; left, $P < 0.037$). At 2 weeks after SNRB, patients with right-sided radiculopathy still had increased BRT, which improved by 6 weeks. Left-sided patients returned to pre-SNRB levels by 2 weeks postoperatively. Leg pain and BRT were not correlated. The authors did not report at which levels the SNRBs were performed, nor did they include functional status information. At all time points, BRT remained faster than previously published minimums; thus, they concluded that the SNRB had an unclear effect on fitness to drive.

Thaler et al[25] evaluated BRT in 46 patients undergoing surgery for lumbar disk herniation at three time points: preoperatively, on the day of hospital discharge (mean, 3.1 days), and at 5-week follow-up. All patients demonstrated longitudinal improvement in BRT. Right-sided patients demonstrated significant improvement in BRT from preoperative to postoperative testing, whereas left-sided patients showed significant improvement from postoperative to follow-up testing (right, $P = 0.018$; left, $P = 0.009$). The authors concluded that patients do not need to be restricted from driving following discharge from the hospital.

Spinal Fusion

Twenty-one patients who underwent lumbar spinal fusion for a variety of reasons were evaluated preoperatively, before hospital discharge, and at 3-month follow-up[15] (Table 6). The authors reported an increase in BRT in the postoperative period, although this was not significant. BRT decreased significantly from the postoperative measurement to the 3-month follow-up assessment ($P = 0.0007$), but the change from preoperative to 3-month follow-up values was not significant. Healthy control subjects had significantly faster BRT at all time points ($P < 0.001$). Based on these findings, the authors concluded that patients could be permitted to continue driving postoperatively and that back pain influenced BRT.

Patients may not experience significant deterioration in braking function after various spinal procedures. This may be because of preexisting impairment in BRT that improves after surgery or the less invasive nature of certain procedures. Until further study can better define postoperative changes in driving ability, surgeons should use caution in permitting patients to drive following lumbar spinal fusion.

Summary

The decision to resume driving after orthopaedic surgery is difficult for both patient and surgeon. According to insurance companies and law enforcement agencies, patients are ultimately responsible for the decision to drive. With appropriate guidance, the surgeon can ensure that the patient makes an informed decision. Published assessments of braking function serve as a useful guideline, but decision-making should be individualized to each patient.

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Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 3-25, 39, and 41 are level II studies.

References printed in **bold type** are those published within the past 5 years.

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