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The Knee

Brake response time after modern total knee arthroplasty: How soon can patients drive?

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ABSTRACT

Background: Recent advances in the performance of total knee arthroplasty may allow for return to driving sooner than the current recommendation of six to eight weeks. The purpose of this study was to evaluate at what time point patients may safely return to driving after modern total knee arthroplasty.
Methods: Thirty-two consecutive patients underwent pre-operative and weekly post-operative assessments of brake reaction time before and for eight weeks after undergoing total knee arthroplasty.
Results: Overall, patients returned to their preoperative baseline brake reaction times by the second postoperative week. There was a significant difference in regard to gender but not laterality or age. Specifically, men achieved preoperative brake reaction times by the first postoperative week and women by the second.
Conclusions: Patients undergoing total knee arthroplasty with a modern perioperative pathway appear to achieve preoperative brake reaction times by the second postoperative week when not taking narcotic pain medication. However, the safe return to driving in each patient must be approached individually. Surgeon discretion to release a patient to drive is always prudent and the decision should be considered on an individual basis.

1. Introduction

Previous studies support restricting patients undergoing total knee arthroplasty (TKA) from driving for at least six weeks [1–3]. The inability to drive can impose significant psychosocial stressors, such as feelings of isolation or issues with dependency, economic hardship, and increased burden on family members [1,4]. With the advent of modern surgical techniques, many aspects of rehabilitation have been improved, including time to discharge from the hospital, less postoperative pain, faster return to full weight bearing and knee range of motion, and overall quicker rehabilitation [5–16]. The purpose of this study was to provide objective clinical data to assist the surgeon's decision on when to release a patient to drive after modern total knee replacement surgery.

Recently, there has been an increased focus on perioperative management strategies that attempt to minimize patient morbidity and the perception of disability after TKA [17–22]. The modern TKA pathway begins well before the patient is taken to the surgical suite with the development of appropriate patient expectations through thorough and accurate preoperative counseling

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[18,20]. With appropriate patient expectations and effective pain management, early postoperative ambulation and accelerated therapy can be initiated.

The current terminology for surgical approaches in TKA is not standardized. The traditional approach for TKA has been described as a 20 to 25 centimeter midline skin incision that is followed by an arthrotomy that allows for easy eversion and dislocation of the patella and full exposure of all three knee compartments at once [23–25]. Newer techniques have emphasized a variety of maneuvers that are referred to as “less” or “minimally” invasive. These maneuvers include smaller skin incisions, less soft tissue violation, emphasis on careful soft-tissue handling, and various “mini” arthrotomy techniques [11,23–29]. The skin incisions tend to be 10–14 cm and are followed by various arthrotomies that subcategorize what are now being referred to as less-invasive and minimally-invasive surgical techniques [24,25]. The least invasive or *minimally* invasive technique is defined as “quadriceps-sparing” [9,12,13,16,23–29]. We refer to the remainder of the approaches as *less invasive*, rather than minimally invasive, as they violate some portion of the quadriceps mechanism, and include the *mini-midvastus* and the *mini-quadriceps-splitting* approaches [10,11,24,25]. There has been no proven advantage of one minimally invasive or less invasive technique over another [24].

The combination of appropriate patient expectations, less invasive surgical techniques, and early ambulation with accelerated therapy creates an effective pathway for reduced narcotic requirements, fewer medication- and anesthetic-related side effects, rapid mobilization, shorter hospital stays, faster rehabilitation, quicker return to independence, and higher patient satisfaction [17–22]. The authors postulated that patients undergoing modern TKA with these techniques would show a significant improvement in time needed to return to preoperative brake reaction (response) times as compared to previous studies.

2. Materials and methods

Prior to enrolling patients, the study protocol was accepted by the Institutional Review Board. Inclusion criteria included consecutive adult patients undergoing unilateral total knee replacement, secondary to osteoarthritis, who possessed a valid driver's license, primarily drove vehicles with automatic transmissions, and utilized the right foot to depress the brake pedal. Patients were excluded if they had prior knee surgery other than arthroscopy. There were no exclusion parameters relating to age, gender, comorbidities, or body habitus.

Informed consent was obtained from all patients. Patients received thorough preoperative counseling, with an emphasis on appropriate perioperative and outcome expectations, and were managed with our current perioperative pain protocol. All surgeries were performed by the senior author (T.L.G.). Utilizing a skin incision no more than 14 cm in length and a mini-midvastus arthrotomy, no more than two centimeters in length, a cruciate-retaining total knee arthroplasty was performed in each case. NexGen® Complete Knee Solution (Zimmer, Warsaw, Indiana) instrumentation and implants were used in all patients. Patellae were resurfaced and all implants were cemented. All incisions were closed over a drain, which was removed on postoperative day one.

Utilizing our current multimodal pain protocol, patients were given oral Celebrex® (Pfizer Incorporated, New York, NY) 400 mg and Oxycontin® (Purdue Pharma L.P., Stamford, CT) 10 mg preoperatively on the morning of surgery. All procedures were performed under epidural anesthesia, with the catheter left in place overnight. On postoperative day one, oral Celebrex® 200 mg once daily, oral Oxycontin® 10 mg twice daily, and oral Percocet® 5/325 mg (Endo Pharmaceuticals, Inc., Chadds Ford, PA) every four hours as needed were initiated, epidurals were removed two to four hours later, and physical therapy was instituted. Patients were discharged with home or outpatient physical therapy. At discharge, Oxycontin® was continued for 10 days and Celebrex® for six weeks. A 30-day supply of Percocet® was also given to be used on an as needed basis.

Brake reaction times were measured preoperatively (baseline) and postoperatively at weekly intervals for eight weeks. Reaction times were obtained using the WT-2000 Tran-sit® Driving Simulator (Advanced Therapy Products, Inc., Richmond, VA)

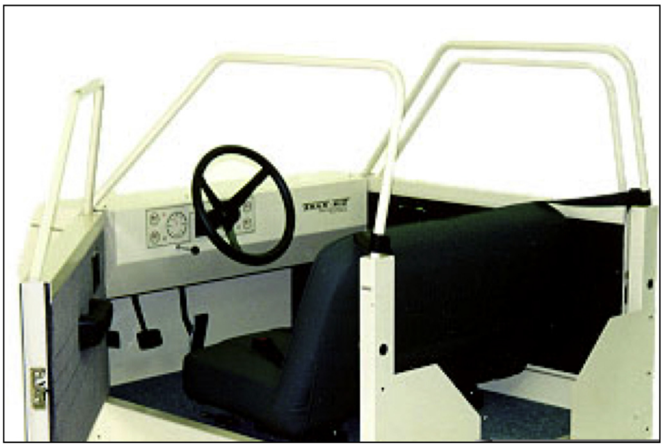

Figure 1. WT-2000 Tran-sit® Driving Simulator (Advanced Therapy Products, Inc. Richmond, VA).

featuring STISIM Drive™ Interactive Driving Software (Systems Technology, Inc., Hawthorne, CA). The simulator consisted of a small, car-shaped frame with an adjustable driver's seat, a steering wheel, and gas and brake pedals (Figure 1). The simulator was positioned in front of a projected video image. Subjects were required to depress the gas pedal, which caused a large green light to appear on the screen. A large stop sign would suddenly replace the green light at random time intervals, at which time the subject depressed the brake pedal as soon as possible. Break reaction time was defined as the time from appearance of the stop sign until initiation of brake pedal depression as detected using the WT-2000 simulator. Brake reaction time was measured to the thousandth of a second at each emergency stop. At each session, patients performed three practice trials and then 10 stops for record. Consistent with prior literature [30,31], the time it took for the foot to come off the gas pedal was not recorded, as break reaction time was defined as the time from appearance of the stop sign until initiation of brake pedal depression. The pressure required to depress the brake pedal on the simulator was consistent with the pressure required to depress the brake pedal on automobiles produced commercially for sale in the United States. For each week, highest and lowest times were eliminated and the remaining eight times averaged. Patients requiring corrective lenses were instructed to wear them at each session. Patients were instructed not to take any narcotics, including Oxycontin®, on testing days until data were obtained. They were also instructed not to take any anti-inflammatories or analgesics within four hours of the testing session. The simulator was operated and reaction time recorded by an occupational therapist.

Statistical analysis for return to baseline was performed, under the supervision of a statistician, with a two-way Analysis of variance (ANOVA) with repeated measures to test the interaction of brake time with gender, age, and laterality. A one-way ANOVA with repeated measures using a Dunnett adjustment was conducted to determine when brake time returned to baseline. Chi Square tests were also performed to compare the counts of individuals returning to baseline by gender, age, or operative side.

Additional analyses were performed to compare measured brake times to the American Automobile Association (AAA) Traffic Safety Department data on age and gender matched historical controls, which categorize norms by percentile rank based on the brake reaction times of 1262 subjects [32]. Chi Square tests were conducted to compare counts of individuals who performed at the 50th percentile. There was no difference in laterality, but because there was a significant gender interaction, patients were separated by gender and then a Wilcoxon Signed Rank Test was conducted to analyze a paired difference between actual braking time and the age- and gender-matched 50th percentile brake response time for each week.

3. Results

Data from 32 consecutive patients meeting the inclusion criteria, 13 males and 19 females, were obtained prospectively. The average age for the group was 62.6 years, (range 43 to 83 years). The average age of men was 63.2 years and the average age of women was 61.5 years. There were 19 right and 13 left TKAs. The average skin incision was 9.8 cm (range 7.3 cm to 13.3 cm) and all Vastus medialis obliquus (VMO) incisions were two centimeters in length.

Average time needed to return to baseline brake reaction time revealed no significant differences in patients aged less than 65 years and those 65 and older. There was no significant difference in regard to laterality—specifically, the average time to return to baseline for right knee reaction time did not differ whether the right or left knee was operated on. Overall, patients showed a statistically significant slower response time at *Week 1*. By *Week 2*, there was no statistical difference in brake times compared to baseline ($p > 0.05$) (Table 1, Figure 2).

In women, *Week 1* brake times were significantly higher than baseline ($p = 0.0045$). By *Week 2*, there was no difference compared to baseline ($p > 0.05$) (Table 2). Female response times improved over time ($p < 0.0001$). In men, there was no significant difference between baseline and brake reaction times at *Weeks 1–8* (Table 3, Figure 3).

When compared to the 50th percentile of age and gender matched control data from the AAA [32], more men reached the 50th percentile by *Week 1* ($p = 0.006$) and *Week 2* ($p = 0.0074$), but there was no difference in the number of men or women who reached the 50th percentile by *Week 3* ($p > 0.05$). On average, female preoperative time was significantly higher than the 50th percentile time ($p < 0.0001$), as were postoperative times at *Weeks 1–5* ($p < 0.05$). Overall, females reached the 50th percentile by *Week 6* (Table 2). The average times for males showed no difference between measured times and the 50th percentile at any time point (Table 3).

Table 1
Overall brake reaction time at baseline (0) and each week (1–8).

Week	n	Mean (s)	Standard deviation (s)	Standard error (s)	p-Value for comparison to baseline
0	32	0.54391	0.17352	0.030674	–
1[a]	31	0.63648	0.28744	0.051625	0.0003[a]
2	31	0.55216	0.17953	0.032244	1.0000
3	23	0.55243	0.14635	0.030515	1.0000
4	26	0.50169	0.15459	0.030317	0.5058
5	22	0.49577	0.15214	0.032436	0.3168
6	17	0.51194	0.17024	0.041290	0.6207
7	16	0.46306	0.12439	0.031098	0.2632
8	10	0.51710	0.15675	0.049570	0.3245

[a] Statistically significant.

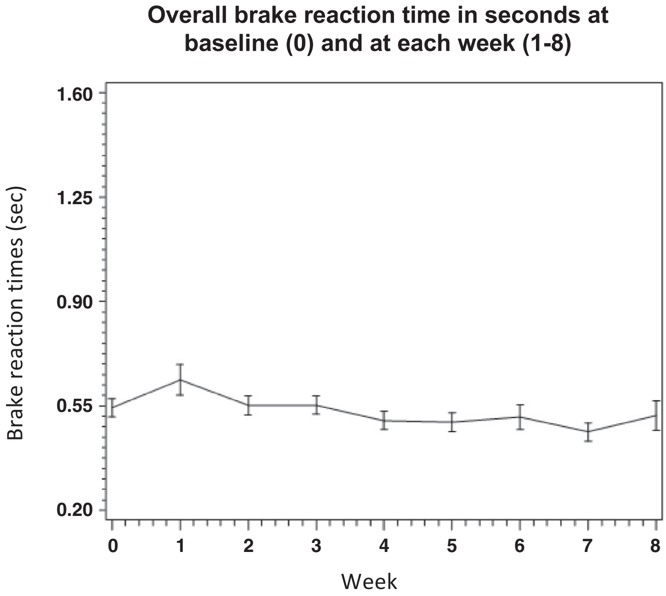

Figure 2. Overall brake reaction times in seconds at baseline (0) and at each week (1–8).

A post-hoc sample size calculation was performed to determine the power of the present study to detect a clinically significant difference between pre-operative and two-week post-operative values. After internal discussions within the group, it was determined that a 0.1 second difference in break reaction time would be considered to be clinically significant. Using the pre-operative mean and standard deviation from the present study (0.54391 ± 0.17352 s), and accepting a two-sided type-I error rate of five percent (alpha = 0.05), the present study with 32 patients had 88% power to detect a 0.1 second change in break reaction time between the pre-operative and two-week post-operative values. Hence, at greater than 80% power, the present study can be considered to be appropriately powered to detect a clinically significant difference.

4. Discussion

The ability to perform an emergency stop is essential for safe driving and can be assessed with brake reaction time (time from releasing the gas pedal to depressing the brake pedal with adequate force) [1–4,33–36]. In a study by Spalding and colleagues [2], brake response times were measured preoperatively and at four, six, eight, and 10 weeks postoperatively in patients undergoing traditional TKA. Eighteen driving patients were available for analysis with an average age of 74 years (61 to 83); 12 had right TKA and six had left TKA. Right TKA was followed by significantly increased brake reaction time at four weeks with return to normal by eight weeks. Brake reaction times were unaffected in those who had left TKA. The authors concluded that patients undergoing right TKA can be released to drive at eight weeks, and those undergoing left TKA may be released as soon as they can depress the clutch pedal with sufficient force for their vehicle [2]. In contrast, the present study suggested that laterality had no significant effect on brake response time. The difference between the two studies can potentially be attributed to improvements in surgical technique, where more modern TKA involves less muscle disruption and soft tissue violation, potentially facilitating recovery in the operative extremity.

Table 2
Female brake reaction time at baseline (0) and each week (1–8).
The first column of p-values indicates statistical difference from baseline, and the second column of p-values indicates statistical difference from the mean 50th percentile break time from historical data of 0.45315 ± 0.06155.

Week	n	Mean (s)	Standard deviation (s)	Standard error (s)	p-Value for comparison to baseline	p-Value for comparison to historical control
0	19	0.60642	0.18094	0.041512	–	<0.0001[a]
1[a]	18	0.71917	0.31599	0.074479	0.0045[a]	0.0001[a]
2	18	0.62467	0.17991	0.042404	0.9998	0.0005[a]
3	16	0.57213	0.15857	0.039644	0.9998	0.0042[a]
4	15	0.56220	0.16981	0.043844	0.6284	0.0181[a]
5	13	0.55954	0.15814	0.043860	0.3058	0.0081[a]
6	12	0.54767	0.18191	0.052513	0.5492	0.064
7	8	0.48725	0.14709	0.052004	0.1732	0.4609
8	7	0.55414	0.17648	0.066705	0.4735	0.1094

[a] Statistically significant.

Table 3
Male brake reaction time at baseline (0) and each week (1–8).
The first column of p-values indicates statistical difference from baseline, and the second column of p-values indicates statistical difference from the mean 50th percentile break time from historical data of 0.47308 ± 0.08835.

Week	n	Mean (s)	Standard deviation (s)	Standard error (s)	p-Value for comparison to baseline	p-Value for comparison to historical control
0	13	0.45254	0.11592	0.032152	–	0.8394
1	13	0.52200	0.20160	0.055915	0.1847	0.3757
2	13	0.45177	0.12617	0.034994	1.0000	0.5879
3	7	0.50743	0.11077	0.041865	1.0000	0.2969
4	11	0.41918	0.07998	0.024114	0.9952	0.2422
5	9	0.40367	0.08422	0.028074	0.9794	0.1641
6	5	0.42620	0.10915	0.048813	0.9997	0.3125
7	8	0.43888	0.10092	0.035680	0.9993	0.5469
8	3	0.43067	0.03353	0.019359	0.8949	0.7500

Pierson and colleagues [1] measured brake response times preoperatively and at three, six, and nine weeks after traditional TKA in 31 patients. Consistent with the current study and in contrast to the study by Spalding and colleagues [2], there was no significant difference in brake response times with regard to laterality. Average brake reaction time was 5.9% slower at three weeks, with significant improvement over baseline at six and nine weeks. When compared to the American Automobile Association National Traffic and Safety data [32], men started in the 56th percentile, had no change at three weeks, but improved to the 59th percentile and then the 66th percentile by six and nine weeks, respectively. Women started in the 12th percentile and fell to the 8th percentile at three weeks. Although they never reached the 50th percentile, females improved to the 33rd and 42nd percentiles at six and nine weeks, respectively [1]. The patients in this study demonstrated a similar trend as brake response time in men remained above the 50th percentile at baseline and at each week, whereas female baseline times were well below the 50th percentile but consistently improved each week. However, the women in this study did reach the 50th percentile at the sixth week. Pierson and colleagues concluded that patients can be released to drive at six weeks postoperatively after either left or right TKA [1].

It was interesting that it was not until week 6 that the females were not statically worse than average age-matched controls. This is in contrast to the men, who ever show any statistical difference from the average age-matched controls. There are two potential explanations for these observed differences. First, it is possible that women may be more impacted by the surgical procedure or the postoperative analgesia than men. However, this would not explain the pre-operative differences from baseline. Equally likely, as there were more women in the study (n = 19) than men (n = 13), it is possible that the statistical test for women was simply better powered and so more likely to show a statistically significant result. Of note, the observed difference in the AAA data between the 50th percentile times for women and men of 0.45 versus 0.47, respectively, are unlikely to be clinically or statistically significantly different—that is, these are essentially not different from each other.

Based on these studies, the current recommendation for return to driving is between six and eight weeks postoperatively for patients undergoing right or left total knee replacement. The current study measured brake response times in patients undergoing

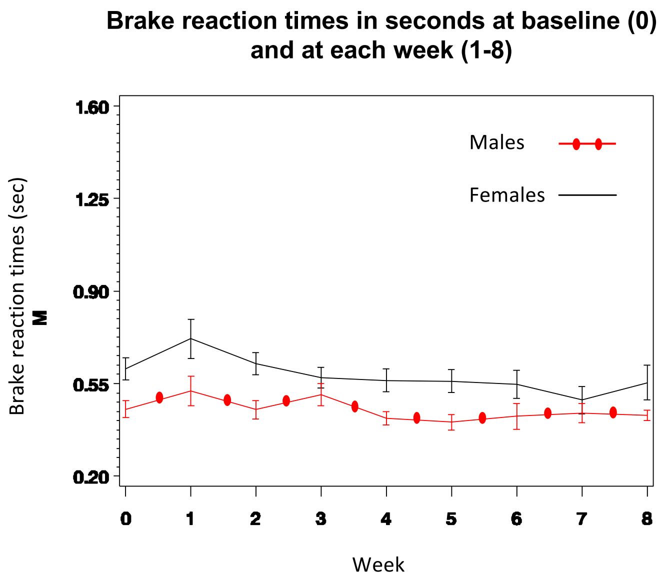

Figure 3. Brake reaction times in seconds at baseline (0) and at each week (1–8).

TKA with a modern perioperative pathway and found that men return to their preoperative break reaction times by the first postoperative week and women by the second postoperative week, regardless of laterality. This information may be utilized by surgeons to help determine when it is safe for patients undergoing TKA, with a modern perioperative pathway, to return to driving.

The present study had several strengths. First, it had an objective and prospective design that included a standardized, single-surgeon, single facility protocol. Second, the design is very similar to previous studies evaluating brake response times after TKA [1,2] allowing meaningful comparison. Third, unlike many of the prior studies noted above, the present study used minimally invasive surgical technique, making results more applicable to the modern approach to TKA. Fourth, the study was well powered, with 88% power to detect a clinically significant difference between the pre-operative and two-week postoperative values, as noted in the post-hoc power analysis at the end of the Results section. This makes the finding of no difference at the two-week mark much more meaningful.

The present study also has limitations. First, the study lacked a control group, and so is exposed to potential susceptibility (selection) bias. For example, the differences between the present study and prior studies may not be attributable to surgical technique; instead, it is possible that patients in the present study were simply younger and healthier and quicker to recover based on personal characteristics. Second, the study is limited by its follow-up; that is, not all patients completed every weekly session, which led to a decreasing number of study points in subsequent weeks and the potential for skewed data. For example, it was not until week 6 that the females in this paper were not statistically worse than average; however, by week 6 only 12 of the original 17 females were tested, and this number drops further in weeks 7 and 8. Fortunately, the reader can note that 18 of the 19 patients were tested at week 2, which is the time point at which it was first noted that there was no difference between pre- and postoperative values. This is reassuring in that for this comparison, on which the primary study conclusion hinges, we had nearly universal follow-up. Third, as this is not a true random sample of the population, the patients in the present study may not be representative of all patients nationwide. This has the potential to bias results towards either more rapid or more delayed recovery. Fourth, the present study did not record postoperative narcotic use. While modern TKA techniques have resulted in decreased postoperative narcotic requirements, the patients in the present study were still provided with a 30-day supply of narcotic pain medication, which some may feel is excessive. It is possible that many patients did not take this full supply, but because postoperative narcotic use was not recorded, this is not possible to confirm. Fifth, the study is limited by the overall small number of patients. Sixth, patients were instructed not to take any narcotics on testing days until data were obtained. As a result, findings might only be applicable for patients off narcotics. Seventh, break reaction time is defined here and throughout the literature as the time it takes for the subject to initiate depression of the brake pedal in response to a stimulus [30,31]. However, this does not consider the extent to which a lower extremity condition might inhibit the ability to generate enough pressure to adequately depress the pedal.

It is assumed that the ability to quickly depress a brake pedal for an emergency stop can be derived from brake response time measurements, and that a rapid response indicates the ability to safely drive. However, the ability to safely drive also involves factors such as cognition, level of alertness, medications, and visual acuity, all of which the treating physician must consider when advising a patient on postoperative return to driving. The reader should again be reminded that the patients in the present study were asked not to take narcotic medication on the day of testing until they had completed the tests; hence, findings are likely only relevant for patients who have stopped narcotic pain medication. Given the safety and legal ramifications of policies regarding safe driving, the limitations of the study with respect to the generalizability of the results and cautious interpretation of the results cannot be over-emphasized. While data provided here should be used as a general guide to assist in surgeon decision-making with respect to allowing patients to return to driving, surgeon discretion is paramount. For the typical patient who is off of narcotics and fits the average demographic descriptions listed above, return to driving at two weeks is likely appropriate. However, for patients in whom the surgeon suspects slower return to normal reaction time for any reason, return to driving should be delayed. Specific government policies are unlikely to be put into place with respect to return-to-driving after specific surgical procedures; hence, timing of return-to-driving will remain the surgeon's decision. However, to provide even better data from which the surgeon can make decisions, future studies might prospectively follow patients who are allowed to return to driving at the two-week postoperative mark. Such studies could follow patients for involvement in motor vehicle accidents and could assess their subjective comfort with driving at that early postoperative time point in order to further clarify the safety of early return-to-driving.

5. Conclusion

Patients undergoing TKA with a modern perioperative pathway appear to achieve preoperative brake reaction times by the second postoperative week when not taking narcotic pain medication. When compared to historical controls [32], female brake response time reached the 50th percentile by the sixth postoperative week and men met the 50th percentile at all time points. The safe return to driving in each patient must be approached individually. Surgeon discretion to release a patient to drive is always prudent and the decision should be considered on an individual basis.

Conflict of interest statement

One of the authors has a financial relationship with Smith and Nephew for purposes of both consulting and research funding. This is not directly relevant to the study at hand. The other two authors do not report any potential conflict of interest.

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