A Novel Assessment of Braking Reaction Time Following THA Using a New Fully Interactive Driving Simulator

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Abstract *Background:* After total hip replacement surgery, patients are eager to resume the activities of daily life, particularly driving. Most surgeons recommend waiting 6 weeks after surgery to resume driving; however, there is no evidence to indicate that patients cannot resume driving earlier. *Questions/Purposes:* Our purpose was to evaluate when in the recovery period following THA that patients regain or improve upon their preoperative braking reaction time, allowing them to safely resume driving. *Methods:* We measured and compared pre- and postoperative braking reaction times of 90 patients from 3 different surgeons using a Fully Interactive Driving Simulator (Simulator Systems International, Tulsa, OK). We defined a return to safe braking reaction time as a return to a time value that is either equal to or less than the preoperative braking reaction time. *Results:* Patients tested at 2 and 3 weeks after surgery had slower braking reaction times than preoperative times by an average of 0.069 and 0.009 s, respectively. At 4 weeks after surgery, however, patients improved their reaction times by 0.035 s ($p=0.0398$). In addition, at 2, 3, and 4 weeks

postoperatively, the results also demonstrated that patient less than 70 years of age recovered faster. *Conclusions:* Based upon the results of this study, most patients should be allowed to return to driving 4 weeks following minimally invasive primary total hip arthroplasty.

Keywords THA · driving simulator · braking reaction time · return to driving

Introduction

“When can I return to driving?” is a common question faced by physicians from patients undergoing total hip arthroplasty (THA). After surgery, patients are eager to resume activities of daily life, particularly driving. However, the braking reaction time (BRT) of a patient undergoing THA increases after surgery, possibly making it unsafe to drive in the immediate postoperative period [4, 6, 7, 9]. When advising a THA patient about when he or she can return to driving, the surgeon must balance the patient’s desire to resume driving, the patient’s safety behind the wheel, and the safety of the general public.

The lack of a legal definition for a safe BRT, and a deficiency of orthopedic practice guidelines in this area, compounded by the patient’s eagerness to return to driving as soon as possible, has made this a difficult question to answer [4, 6, 9]. Several studies and traffic authorities have identified BRT thresholds, ranging from 700 to 1500 ms, but none of these has been recognized as the established safe BRT [5, 6, 9]. Most surgeons recommend that patients wait 6 weeks after surgery to resume driving due to the worry of hip dislocation; however, there is no evidence, as far as braking reaction times are concerned, to indicate that patients cannot resume driving earlier. Many hospitals collect patient reported outcomes, but these validated instruments do not collect responses about ability to drive [2].

In recent years, there has been a trend toward minimally invasive hip implant surgery, which reduces the size of the

Levels of Evidence: Level II Prognostic Study

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incision and dissection of muscle tissue. The reduced trauma to the muscle may improve postoperative muscle function, such as BRT, which would allow patients to return to driving sooner than 6 weeks after surgery. Thus, the purpose of this study was to provide surgeons with objective data that they could use when advising their patients about returning to driving following THA. Other studies have examined BRT after THA, but our driving simulator is much more modern, with a video screen endorsed by the American Automobile Association (AAA) that realistically depicts the dashboard and road view a driver might actually see. Thus, the use of a simulator with a more realistic driving experience may reflect more realistic BRTs than previous studies with more rudimentary devices. The objective data, collected with a driving simulator, consisted of measuring the BRTs of three groups of patients at various time points after surgery to determine which week after surgery was a safe time at which a patient could return to driving. The research questions posed were (1) how quickly do THA patients regain their preoperative braking reaction time, and (2) do any demographic factors such as age influence recovery of braking reaction time?

Patients and Methods

Ninety patients from 3 different surgeons at the same hospital were enrolled in a study to assess their BRTs using a Fully Interactive Driving Simulator (Model S-4150D, Simulator Systems International; Tulsa, OK) with an automatic brake reaction timer from AAA. The reaction timer simulates driving with a steering wheel, accelerator, brake pedal, and a driving simulator video screen also endorsed by AAA (Fig. 1). Patients were instructed to step on the accelerator pedal, which activates the simulation of a car driving down a flat dry road with no other cars. When a stop sign appeared on the screen after a random amount of time, subjects were instructed to switch their foot to the brake pedal as quickly as possible. Patients were allowed to practice this simulation three times, and then took five test trials. Braking reaction times were recorded by the machine as the number of seconds it took the patient to fully depress the brake pedal after the stop sign was displayed. The average BRT was calculated from the five test trials of each patient.

Our inclusion criteria permitted licensed drivers between the ages of 40 and 80 undergoing minimally invasive right THA via a posterior approach for a primary diagnosis of osteoarthritis. Exclusion criteria removed patients undergoing bilateral THA, patients who could not come back for their assigned follow-up visit, patients that drive a manual transmission car, patients that have not driven a car during the 3 months prior to surgery, and patients that did not understand the instructions in order to operate the simulator. Postoperative physical therapy was standardized within the institution where the patients began ambulating on the same day with a walker and progressed as indicated. Patients were randomized into follow up groups (2, 3, or 4 weeks postoperatively, + or – 2 days) at time of consent. Randomization was done by a computer-generated randomization table, but no one was blinded to the

randomization group. BRT was recorded preoperatively and again at their postoperative follow-up appointment. The power analysis determined that 30 patients were needed for each time point in order to arrive at reliable estimates of differences in braking reaction time between the 3 groups.

Descriptive statistics were computed for patient demographics, and preoperative and postoperative braking reaction time (Table 1). Mean and standard deviation were calculated for continuous variables and frequencies and percentages for categorical variables. The difference between preoperative braking reaction time and postoperative braking reaction time was compared using the Wilcoxon signed rank test for each follow-up group. The Kruskal–Wallis test was used to compare the preoperative, postoperative braking reaction times, and the change in reaction time from preoperative to follow-up times between the three follow-up groups. The association between follow-ups and change in reaction time was also analyzed using multiple linear regressions, adjusting for patients' age and preoperative reaction time. Statistical analyses were performed using SAS for Windows 9.3 (SAS Institute Inc., Cary, NC, USA). All tests were two-sided, and a statistically significant result was noted when p value was <0.05 .

Results

The three follow-up groups displayed no significant differences in their average preoperative braking reaction times. The mean reaction time of the 2, 3, and 4 week follow-up groups were 0.793 ± 0.180 , 0.798 ± 0.253 , and 0.751 ± 0.190 , respectively (Kruskal–Wallis test $p=0.4841$). However, the groups displayed significant differences in postoperative braking reaction times. The mean reaction time of the 2, 3, and 4 week follow-up groups were 0.862 ± 0.258 , 0.808 ± 0.254 , and 0.716 ± 0.118 , respectively (Kruskal–Wallis test $p=0.0352$) (Fig. 2).

The BRTs for patients tested at 2 and 3 weeks after surgery were increased compared to preoperative BRTs, indicating a poorer response. The reaction time of the 2-week follow-up group increased by 0.069 ± 0.212 s ($p=0.0899$, Signed rank test), while the reaction time of the 3-week follow-up group increased by 0.009 ± 0.346 s ($p=0.9161$). Patients in the 4-week follow-up group improved their reaction time by 0.035 ± 0.204 s ($p=0.6320$). Although the change in the reaction time was not found to be significantly different between the three follow-up groups in the univariate analysis (Kruskal–Wallis test $p=0.2560$), the effect became significant in the multivariate regression analysis, after controlling for age and preoperative reaction time ($p=0.0398$) (Table 2).

It was observed that younger patients (age <70) reached an improved reaction time earlier than older patients (age ≥ 70). At 2 weeks, 91.7% (11 of 12 patients) that improved their reaction time were younger than age 70. At 3 weeks, 80% (12 of 15 patients) that improved their reaction time were younger than age 70, and at 4 weeks, 81.3% (13 of 16 patients) had a similar finding. However, this association did not reach statistical significance (Cochran–Mantel–Haenszel

Fig. 1. An image of the Fully Interactive Driving Simulator's screen, steering wheel, and pedal system.

test $p=0.5590$). There was no significant difference among the mean ages of the patients in each follow-up group (2 weeks: mean age 62.50 ± 7.1 ; 3 weeks: 62.45 ± 7.77 ; 4 weeks: 64.14 ± 8.56) ($p=0.6334$).

Discussion

We defined a return to safe driving as a return to a braking reaction time that is either equal to or less than the preoperative braking reaction time. According to our data, there is no statistically significant difference between pre- and postoperative BRTs for the 2- and 3-week groups, although the reaction times appear to increase slightly compared to preoperative

values, albeit, not by a statistically significant increase. Thus, conclusions about safely returning to driving at these time points cannot be determined with our study's data. However, at 4 weeks following surgery, patients have significantly improved their BRTs compared to their preoperative baseline, and therefore can safely be cleared to resume driving.

Our study has several limitations. Patients were not screened or excluded for potentially confounding comorbidities at the time of enrollment. Thus, some patients may have had physical conditions or impairments (such as bad eyesight) that also affected their BRTs. However, mitigating this limitation is the fact that we only tested patients that were licensed drivers. Secondly, a more ideal study design would be to have each patient return for a 2, 3, and 4 week follow up visit, but this was impractical. Thirdly, though it would have helped us compare our results to other studies in the literature, we did not evaluate a 6-week follow-up group. Fourthly, we did not record the use of narcotic pain medication by the patients enrolled in this study. Most patients stop taking narcotic pain medication by 4 weeks after THA. Thus, it is possible that the slower braking reaction time at 2 and 3 weeks after surgery could be explained by the use of narcotic pain medication. Finally, we only evaluated patients with routine primary THA surgery and excluded more complex cases such as patients that require removal of hardware or revision surgery.

One of the earliest simulator studies done by MacDonald et al. from 1988 demonstrated in a cohort of 25 patients that reaction times improved by 8 weeks following hip surgery based on previous recommendations for appropriate recovery time [7]. Since this study, surgical technique and rehabilitation of THA have certainly improved.

Ganz et al. measured driving reaction time in total hip arthroplasty patients preoperatively and at 1 week, 4 to 6 weeks, 26 weeks, and 52 weeks, postoperatively [4]. They found that patients' reaction time increased (that is, worsened) 1 week postoperatively, and then improved at every other point postoperatively. Another study by Jorden et al. used a custom-made model car to measure total brake response time (TBRT), but also movement time (MT) and brake force (BF) [6]. However, they used follow-up times of 8 days and then not again until 6 weeks. Therefore, they found that mean MT and TBRT increased and BF decreased at 8 days postoperatively, and initial preoperative values were reached at week 6 following THA. Historically, patients have reported feeling most comfortable to drive by 6–8 weeks postoperatively [1, 8, 9]. Because the authors did not bring in patients between 1 and 4 weeks postoperatively, we did not previously know whether patients regain a safe reaction time before the 4–6 week time period. Our study results demonstrate an overall improvement of patients' BRTs at 4 weeks post right THA.

Several studies have reported threshold values for safe BRTs, ranging from 700 to 1500 ms, but these values have not been established by law or by orthopedic practice [6, 9]. The BRTs of our study reflect the findings of a study by Green [5], which has been frequently cited by studies about BRTs after THA [6, 9]. Green states that alert drivers expecting a braking signal will demonstrate a BRT between 700 and 750 ms. But drivers presented with a normal but unexpected braking signal, such as the brake lights of the car ahead of the

Table 1 Preoperative demographic differences between cohorts, controlled for by randomization

	N	Age		Difference in reaction time		Female	
		Mean	SD	Mean	SD	N	%
Follow-up group							
2 week	30	62.50	7.10	0.07	0.21	21	70%
3 week	29	62.45	7.77	0.01	0.35	11	37.93%
4 week	31	64.14	8.56	−0.03	0.20	16	51.61%
P value		0.6334		0.2988		0.0462

Fig. 2. There were no significant differences in preoperative reaction time values between the three groups (with follow-up at 2, 3, and 4 weeks), but there were significant differences between postoperative reaction time values.

driver, will take as long as 1250 ms to move their foot to the brake pedal, and even up to 1500 ms for patients presented with irregular and unexpected braking signals, such as an object in the road. Notably, Ganz et al. (2003) reported average BRTs ranging from 450 to 590 ms, remarkably below the 700 ms indicated as “threshold” by other studies [4, 6, 9]. Because there is no defined safe BRT [4, 6, 9], the average BRT of the 4-week cohort in our study should not be considered a definitive, safe BRT. Our study simply demonstrates that the patients with 4-week follow-up had, on average, either regained or improved upon their preoperative BRT. Patients in the 2- and 3-week follow-up cohorts, though, had BRTs slower than their preoperative BRT.

An anonymous driving questionnaire was given by Chen et al. to a cohort of urban area patients who underwent a variety of surgical procedures including arthroplasty [3]. Results showed that many patients did not consult their doctor before returning to driving. Many of these patients also reported that the inability to drive was a major financial hardship as well as a burden with dependence on family or friends to drive [3]. Allowing patients to safely return to driving at 4 weeks may greatly improve patient satisfaction.

Previous research had shown that older patients have worse reaction time while driving [10]. However, Ganz et al. did not

evaluate subjects by age [4]. Therefore, conclusions were not made regarding differences in reaction time for patients of different age groups. Our study did not follow the same group of patients from 2 to 4 weeks, so it is difficult to conclude that age affected reaction times of our patient population. However, across all the follow-up groups in our study, more patients under 70 years of age accomplished an improved reaction time at their postoperative visit than did patients greater than 70 years of age.

The American Occupational Therapy Association (AOTA) recommends a comprehensive evaluation of a patient’s driving abilities that involve an office evaluation as well as a driving simulation [3]. Unfortunately, this is neither standard of care nor financially feasible in many orthopedic practices. Therefore, a study such as ours is useful for surgeons to know that a cohort of patients recovering from THA has successfully achieved a BRT as fast as their preoperative BRT by 4 weeks after THA.

By using a standardized, validated driving simulator to measure BRT, our study design may also prove useful to test other orthopedic procedures that could affect a patients’ ability to drive safely after surgery. While we demonstrated in this study that a patient’s BRT improved by 4 weeks postoperatively, clinicians must always take into account unique circumstances such as more complicated THA

Table 2 Comparison of average reaction times between the three groups (with follow-up at 2, 3, and 4 weeks) and between pre- and postoperative reaction times

Follow-up group	Pre-op reaction time			Post-op reaction time			Δ Reaction time		
	Mean	SD		Mean	SD		Mean	SD	p value
2 week	0.793	±0.180	$p=0.4841$	0.862	±0.258	$p=0.0352$	+0.069	±0.212	$p=0.0899$
3 week	0.798	±0.253		0.808	±0.254		+0.009	±0.346	$p=0.9161$
4 week	0.751	±0.190		0.716	±0.118		-0.035	±0.204	$p=0.0398$

surgery that may require additional recovery time before recommending a return to safe driving.

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Disclosures

Conflict of Interest: Allison V. Ruel, BA, Yuo-yu Lee, MS, and John Boles, BS have declared that they have no conflict of interest. Friedrich Boettner, MD reports personal fees from Orthodevelopment, DJO, Smith and Nephew, outside the work. Edwin Su, MD reports grants and personal fees from Smith and Nephew, outside the work and is an editor for the American Journal of Orthopaedic Surgery. Geoffrey H. Westrich, MD reports grants and personal fees from Stryker Orthopedics, Exactech and DJO, outside the work and is a board member of the Knee Society and committee member of the Knee Society and a board member of the Eastern Orthopedic Association.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was obtained from all patients for being included in the study.

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