When Is It Safe to Return to Driving After Spinal Surgery?

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Abstract

Study Design Prospective study.

Objective Surgeons' recommendations for a safe return to driving following cervical and lumbar surgery vary and are based on empirical data. Driver reaction time (DRT) is an objective measure of the ability to drive safely. There are limited data about the effect of cervical and lumbar surgery on DRT. The purpose of our study was to use the DRT to determine when the patients undergoing a spinal surgery may safely return to driving.

Methods We tested 37 patients' DRT using computer software. Twenty-three patients (mean 50.5 $\pm$ 17.7 years) received lumbar surgery, and 14 patients had cervical surgery (mean 56.7 $\pm$ 10.9 years). Patients were compared with 14 healthy male controls (mean 32 $\pm$ 5.19 years). The patients having cervical surgery were subdivided into the anterior versus posterior approach and myelopathic versus nonmyelopathic groups. Patients having lumbar spinal surgery were subdivided by decompression versus fusion with or without decompression and single-level versus multilevel surgery. The patients were tested preoperatively and at 2 to 3, 6, and 12 weeks following the surgery. The use of opioids was noted.

Results Overall, the patients having cervical and lumbar surgery showed no significant differences between pre- and postoperative DRT (cervical $p = 0.49$, lumbar $p = 0.196$). Only the patients having single-level procedures had a significant improvement from a preoperative DRT of 0.951 seconds (standard deviation 0.255) to 0.794 seconds (standard deviation 0.152) at 2 to 3 weeks ($p = 0.012$). None of the other subgroups had a difference in the DRT.

Conclusions Based on these findings, it may be acceptable to allow patients having a single-level lumbar fusion who are not taking opioids to return to driving as early as 2 weeks following the spinal surgery.

Keywords
- return to driving
- lumbar surgery
- cervical surgery
- driver reaction time

* The Institutional Review Board of University of California Los Angeles approved this study protocol (Approval number: #10-001893).

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Introduction

A question frequently asked of surgeons is when a patient may return to driving after a given procedure.[1,2] The safety of the patient and the public must be weighed against the impact that an extended period of being unable to drive would have on the quality of life of the patient.[3]

A patient's cognitive state, sensory motor coordination, experience, and fatigue and the local environment all contribute to driving ability. However, one factor universally agreed upon is the ability to stop in an emergency; this can be measured as driver reaction time (DRT).[4] The DRT has been studied for many different orthopedic procedures of the lower extremity.[5–10] However, there are few studies about DRTs in patients after spinal surgery. This lack of data makes it difficult for surgeons to provide patients with accurate information about when they may return to driving.

Al-khayer et al performed a prospective study of patients receiving nerve blocks of the lumbar spinal nerves and showed a small increase in DRTs at 2 weeks postoperatively, which resolved by 6 weeks postoperatively.[4] Likewise, Liebensteiner et al performed a prospective study of patients who had lumbar fusion surgery and found that the DRT was not significantly increased at 1 week after the surgery.[11] Thaler and colleagues demonstrated that patients who had lumbar disk surgery for radiculopathy showed a significant improvement in DRT at discharge compared with preoperatively; the same researchers also showed similar improvement in DRT on discharge after anterior cervical decompression and fusion (ACDF) for cervical radiculopathy.[12,13] Finally, in a recent post hoc analysis of data from a large prospective study, Kelly et al found that patients undergoing either ACDF or cervical single-level arthroplasty had no difficulty with driving based on a neck disability questionnaire by postoperative 6 weeks.[14]

Our purpose was to perform a prospective study of patients receiving cervical or lumbar spinal surgery and measure their DRTs preoperatively and at first (2 to 3 weeks), second (6 weeks), and third (12 weeks) follow-up visits to determine when DRT returned to preoperative levels. We hypothesized that the patients would have an increase in DRTs at 2 to 3 weeks postoperatively, which would return to normal by 6 to 12 weeks postoperatively. We planned to analyze subgroups of these patients based on anterior or posterior surgical approach and on myelopathic or nonmyelopathic groups. The lumbar spine surgery group was divided into multi- or single-level surgery and by decompression alone or those who had had fusion with or without decompression. We expected the subgroups receiving multilevel fusion and those patients who were myelopathic would have a larger and longer-lasting increase in DRTs.

Methods

Participants

Between September 2008 and July 2011, 14 patients receiving cervical spine surgery and 23 patients receiving lumbar surgery were enrolled in the study. Patients were excluded from the study if they did not have a valid driver's license, were no longer operating a vehicle, or had a prior surgery within the previous year. The participation was voluntary, and no incentives were given to patients. The experiment was conducted under the approval of the UCLA Institutional Review Board. The surgeries were performed by one of the two senior surgeons.

In all, 17 men and 6 women (mean age 50.5 ± 17.7 years) received lumbar surgery, for a total of 23 patients. Nine patients received single-level surgery and 14 received a multilevel surgery. In total, 11 patients underwent surgery involving decompression alone and 12 received fusion with or without decompression surgery (►**Table 1**). Eight women and 6 men had cervical surgery (mean age 56.7 ± 10.9 years), and 5 patients had anterior cervical surgeries. Nine patients had the surgery via a posterior approach. One patient had both anterior and posterior surgeries and was included in the posterior surgery group. There were 11 patients with myelopathy and 3 without (►**Table 1**). Using Chile's modified Japanese Orthopaedic Association myelopathy scale, the average score was 15.45 ± 0.69. All the patients in the cervical group completed the pre- and postoperative DRT testing (100%). However, only 6 patients completed the DRT testing at 6 weeks (42%), and 5 patients completed the testing at 12 weeks (36%). In the lumbar group, 21 of 23 patients completed the postoperative testing at 2 weeks (91%), 8 patients completed the testing at 6 weeks (35%), and 15 patients completed the testing at 12 weeks (65%). The patients were compared with a control group of 14 healthy men (mean age 32 ± 5.19 years).

Table 1 Demographic data

	Cervical	Lumbar
Mean age (y)	56.7 ± 10.9	50.5 ± 17.7
Male:female	6:8	17:6
Single level:multilevelsurgery	NA	9:14
Decompression:fusion with or without decompression	NA	11:12
Anterior:posterior	5:9	NA
Myelopathic:nonmyelopathic	11:3	NA
Total	14	23

Abbreviation: NA, not applicable.

Procedure

DRT was measured using commercial computer instrumentation and software (Vericom Reaction Timer; Rogers, Minnesota, United States).[15] The patients were given instructions and the chance to practice on the simulator. The patients then performed 15 separate successful simulations where they responded to a stimulus and reacted accordingly. A successful simulation meant the patient responded correctly. The simulation started with the patient holding the gas pedal down a predetermined amount, which was represented on the system by the speedometer measuring between 35 and 65 mph. The software then recorded the response time to five different stimuli: left turn, right turn, brake, brake + left turn, brake + right turn. The patients were tested preoperatively and then postoperatively at 2 to 3, 6, and 12 weeks following the surgery. At the postoperative visits, the patients were given the opportunity to do up to 5 practice simulations. The control group was tested once using the same protocol.

Statistical Analysis

The paired *t* test was used to compare the preoperative and 2- to 3-week postoperative reaction times. In the case of nonparametric data, Wilcoxon signed rank test was substituted. Linear mixed-effects regression modeling was used to compare the preoperative reaction times through 12-week postoperative values. This method was chosen over analysis of variance because the data were not assumed to be independent across a given patient's successive reaction times and because it allowed the authors to analyze the data with missing values. The preoperative times of all the groups and subgroups were compared with the control group using unpaired *t* test analysis, and the Mann-Whitney test was used for the nonparametric data. The independent sample *t* test was used to assess for the correlations between opioid use and reaction time. In the case of nonparametric data, the Wilcoxon-Mann-Whitney test was substituted. The Spearman correlation was used to the compare reaction times and visual analog scale (VAS) scores. All data analysis was performed using STATA (StataCorp, College Station, Texas, United States).

Results

Cervical

The 14 patients who had cervical surgery had a mean preoperative DRT of 0.976 seconds (standard deviation [SD] 0.242); the DRT at the first postoperative visit was slightly higher at 1.007 seconds (SD 0.312; $p = 0.49$). There was significant patient attrition at the 6- and 12-week postoperative appointments. Of the 6 patients who followed up at 6 weeks, the DRT decreased to 0.908 seconds (SD 0.234), though at 12 weeks, it increased to 0.936 seconds (SD 0.303). The mixed-effects regression analysis through the 12-week postoperative visit showed that there was no change in the DRT ($p = 0.851$; ►**Table 2**, ►**Fig. 1**).

When broken down by patients with myelopathy and patients without myelopathy, there was still no difference between the pre- and postoperative mean DRT for either group. There was a general trend for increased DRTs; however, those changes were small. The DRT of the myelopathic group was 0.993 seconds (SD 0.267) preoperatively and 1.021 seconds (SD 0.340) postoperatively ($p = 0.554$). The mean DRT of the nonmyelopathic group was 0.917 seconds (SD 0.127) preoperatively and 0.957 seconds (SD 0.227) postoperatively ($p = 0.697$). The mixed-effects regression analysis showed no difference in the DRT across the 12-week period for the myelopathic ($p = 0.908$) or nonmyelopathic groups ($p = 0.582$; ►**Table 2**, ►**Fig. 1**).

The analysis of anterior and posterior surgeries also showed no difference between the pre- and postoperative reaction time for either group, though there continued to be a trend for slight increase in the DRT postoperatively at 2 to 3 weeks. The mean DRT for the anterior group increased slightly from 0.814 seconds (SD 0.125) preoperatively to 0.818 seconds (SD 0.119) postoperatively ($p = 0.893$). The mean DRT for the posterior group was 1.067 seconds (SD 0.248) preoperatively and 1.112 seconds (SD 0.341) postoperatively ($p = 0.423$). The mixed-effects analysis of the DRT revealed no significant difference across all visits for either the anterior ($p = 0.899$) or the posterior groups ($p = 0.824$; ►**Table 2**, ►**Fig. 1**).

Table 2 Mean driver reaction time (in seconds) after cervical surgery

Patients	Reaction time			
	Preoperative	Postoperative[a]	6 wk postoperative	12 wk postoperative[b]
Overall	0.976 ± 0.242	1.007 ± 0. 312 ($p = 0.490$)	0.908 ± 0.234	0.936 ± 0.303 ($p = 0.851$)
Myelopathic	0.993 ± 0.267	1.021 ± 0. 340 ($p = 0.554$)	–	– ($p = 0.908$)
Nonmyleopathic	0.917 ± 0.127	0.957 ± 0. 227 ($p = 0.697$)	–	– ($p = 0.582$)
Anterior	0.814 ± 0.125	0.818 ± 0. 119 ($p = 0.893$)	–	– ($p = 0.899$)
Posterior	1.067 ± 0.248	1.112 ± 0. 341 ($p = 0.423$)	–	– ($p = 0.824$)

[a]Wilcoxon *t* test.
[b]Mixed-effect analysis.

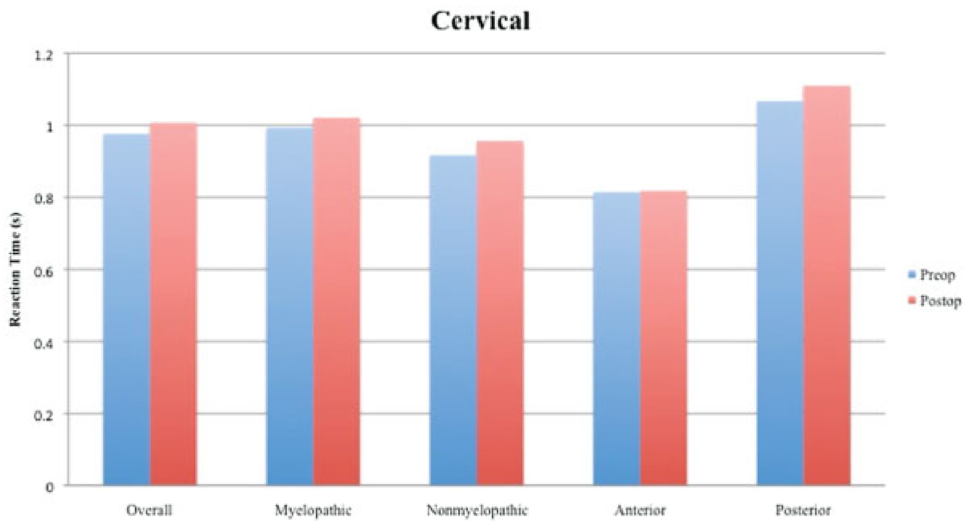

Fig. 1 The mean driver reaction time (DRT) of patients having cervical surgery at the preoperative and first postoperative visit (2 to 3 weeks after surgery). There was no significant difference in pre- and postoperative DRT for the entire cervical group or any of the anterior approach, posterior approach, myelopathic, or nonmyelopathic groups.

To assess whether pain played any role in the changes in DRT, we compared the preoperative and postoperative DRTs to the patient's self-reported VAS score but found no correlation. The preoperative Spearman rho was 0.218 ($p = 0.472$), and the postoperative Spearman rho was 0.125 ($p = 0.684$; ►**Fig. 2**). We also found no relationship between the DRT and opioid use either pre- ($p = 0.089$) or postoperatively ($p = 0.199$; ►**Fig. 3**).

The mean DRT of the control group was 0.762 seconds (SD 0.091). That was significantly faster than every cervical group at both pre- and postoperative visits except the anterior cervical approach group (presurgical $p = 0.521$; postsurgical $p = 0.3$).

Lumbar

Overall, the 23 patients who received lumbar surgery showed a trend toward decreased DRT. For all the lumbar patients, the mean DRT was 1.012 seconds (SD 0.222) preoperatively and 0.953 seconds (SD 0.222) at the first 2- to 3-week follow-up visit ($p = 0.196$). At 6 weeks, the mean DRT was 0.842 seconds (SD 0.071) and at 12 weeks it was 0.946 seconds (SD 0.133) The mixed-effects analysis revealed no significant difference in the DRT across all visits ($p = 0.110$; ►**Table 3**, ►**Fig. 4**). The Spearman rho analysis of the VAS scores revealed no correlation of pain and DRT. The preoperative Spearman rho was −0.199 ($p = 0.364$) and the postoperative Spearman rho was 0.011 ($p = 0.964$; ►**Fig. 5**). Likewise, there was no detectable effect of opioid use on the preoperative ($p = 0.327$) or postoperative ($p = 0.353$) reaction times (►**Fig. 6**).

Patients in the lumbar group were then further analyzed by single- versus multilevel surgery. The single-level group had a mean preoperative DRT of 0.951 seconds (SD 0.255) and a mean postoperative DRT of 0.794 seconds (SD 0.152), which reached statistical significance ($p = 0.012$). Conversely, the mean DRT of the multilevel group was 1.051 seconds

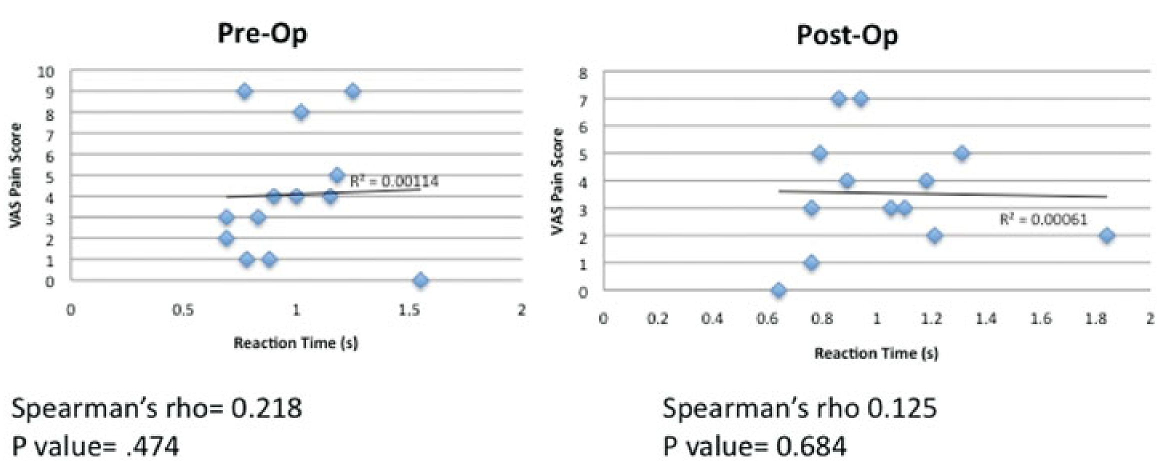

Fig. 2 Visual analog scale (VAS) score correlation with driver reaction time after cervical spine surgery. Spearman correlation was used to compare reaction times and VAS scores of patients after cervical spine surgery. There was no statistical relationship either before ($p = 0.474$) or after surgery ($p = 0.684$) between VAS and driver reaction time.

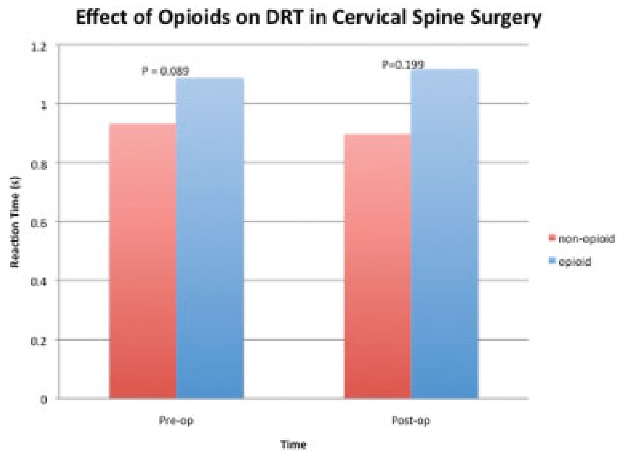

Fig. 3 Opioid use and driver reaction time (DRT) in cervical spine surgery. We used an unpaired *t* test analysis to examine whether there was a relationship between patient opioid use and DRT. We found no relationship either preoperatively ($p = 0.089$) or postoperatively ($p = 0.199$).

(SD 0.197) preoperatively and 1.052 seconds (SD 0.204) postoperatively ($p = 0.950$). For the single-level surgeries, the mixed-effects regression analysis had a p value of 0.008, indicating decreased DRT across the postoperative visits. Conversely, the multilevel surgery group mixed-effects analysis revealed no postoperative difference across all four visits ($p = 0.123$; ►**Table 3**, ►**Fig. 4**).

When the lumbar group was broken down into the patients who had received fusion with or without decompression and the patients who had received decompression alone, the fusion group's mean DRT was 1.077 seconds (SD 0.136) preoperatively and 1.046 seconds (SD 0.232) postoperatively ($p = 0.713$). The decompression-only group's mean preoperative DRT was 0.952 seconds (SD 0.270), which decreased to 0.884 seconds (SD = 0.198) at the first postoperative visit ($p = 0.117$). The mixed-effects regression analysis of the fusion group ($p = 0.229$) and the decompression group ($p = 0.275$) showed no significant change across all postoperative visits ($p = 0.229$; ►**Table 3**, ►**Fig. 4**).

Again, every lumbar group was significantly slower than the control mean DRT of 0.762 seconds (SD 0.091) preoperatively. Postoperatively, only the single-level group ($p = 0.691$) and the decompression groups were not different than the control group ($p = 0.128$).

Discussion

The goal of this study was to establish when a patient's DRT returns to baseline after a spinal surgery. Although there are many subjective factors that contribute to a patient's ability to safely drive, one agreed-upon objective factor is DRT.[16] There is very limited literature on when post–spinal surgery DRT returns to preoperative times for the patients having lumbar surgery, and only two studies, focusing on ACDFs, for cervical surgery. Similarly to Liebensteiner et al and in contrast to Al-khayer et al, we found that lumbar patients' DRT at their first postoperative visit was not different from their preoperative DRT.[4,11] There was a trend for the lumbar surgery group as a whole to have improved DRTs between their preoperative and first postoperative visit. In the single-level surgical group, this improved DRT actually reached significance. The group that received decompression alone also approached statistical significance for improved DRT postoperatively. This was similar to the results found by Thaler et al, who showed that the postoperative DRT actually improved compared with the preoperative DRT for patients receiving lumbar disk surgery for radiculopathy.[12] As results were either improved or not statistically different from the preoperative groups, we feel comfortable stating that some patients having lumbar surgery, especially single-level surgery or decompression only, may consider return to driving at 2 weeks based on the DRT, although other factors especially including severity of disease, amount of muscular dissection performed, and baseline functional status must be taken into account.

It is not immediately clear why our results differ from that of Al-khayer et al and support Liebensteiner et al and Thaler et al.[4,11,12] It is possible that the nerve blocks studied by Al-khayer et al had a greater effect on DRT than the fusions

Table 3 Mean driver reaction time (in seconds) after lumbar surgery

Patients	Reaction time			
	Preoperative	Postoperative[a]	6 wk postoperative	12 wk postoperative[b]
Overall	1.012 ± 0.222	0.953 ± 0.222 ($p = 0.196$)	0.841 ± 0.071	0.945 ± 0.133 ($p = 0.110$)
Single level	0.951 ± 0.255	0.794 ± 0.152 ($p = 0.012$)	–	– ($p = 0.008$)
Multilevel	1.051 ± 0.197	1.052 ± 0.204 ($p = 0.950$)	–	– ($p = 0.123$)
Fusion	1.077 ± 0.136	1.046 ± 0.232 ($p = 0.713$)	–	– ($p = 0.229$)
Decompression	0.952 ± 0.270	0.884 ± 0.198 ($p = 0.117$)	–	– ($p = 0.275$)

[a]Wilcoxon *t* test.
[b]Mixed-effect analysis.

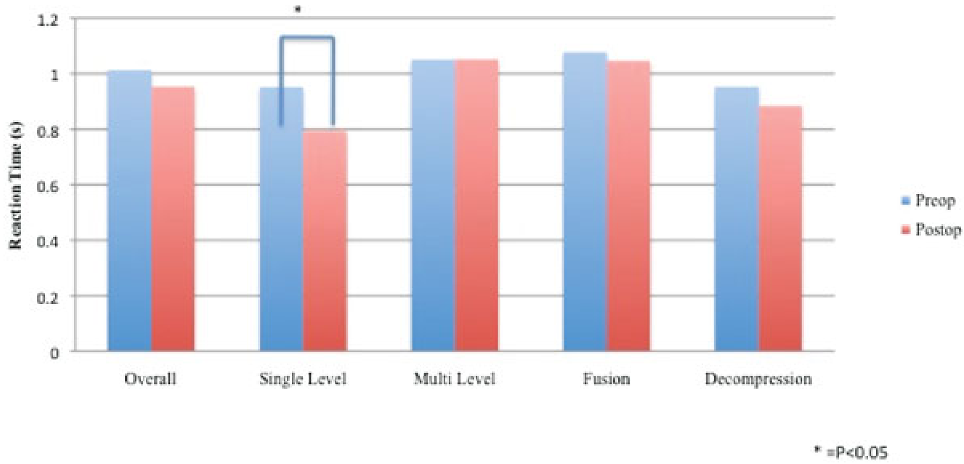

Fig. 4 The mean driver reaction time (DRT) of patients having lumbar surgery at the preoperative and first postoperative visit (2 to 3 weeks after surgery). There was no significant difference in pre- and postoperative DRT for the entire lumbar group or any of the subgroups, except the single-level surgical group, which was improved.

studied by Liebensteiner et al or the fusions and/or decompressions in our study because of the direct effect of selective nerve root block anesthesia on nerve roots. Interestingly, like Al-khayer et al,[4] we found no relationship between the self-reported pain and DRT; however, Liebensteiner et al did find a correlation between the pain and DRT. It is possible that the brake used by Liebensteiner et al required greater force to compress and thus was more affected by the pain.[11] In contrast, Thaler et al showed a statistically significant improvement in DRT postoperatively at discharge for the patients receiving surgery for lumbar radiculopathy.[12] Their patient group's more dramatic improvement was likely due to their described minimal surgical dissection and resolution of radicular pain, unlike our more heterogeneous patient population that likely continued to have some effect from chronic pain and the surgery at the first postoperative visit.[12]

To the best of our knowledge, only two other studies have addressed DRT after cervical surgery. Lechner et al found that the patients receiving ACDF for cervical radiculopathy had significant improvement in DRT at the time of discharge and recommended that it was safe for them to return to driving.[13] Kelly et al performed a post hoc analysis of patients' self-reported driving disability from neck pain on patients involved in an investigational device exemption study of ACDF and cervical arthroplasty

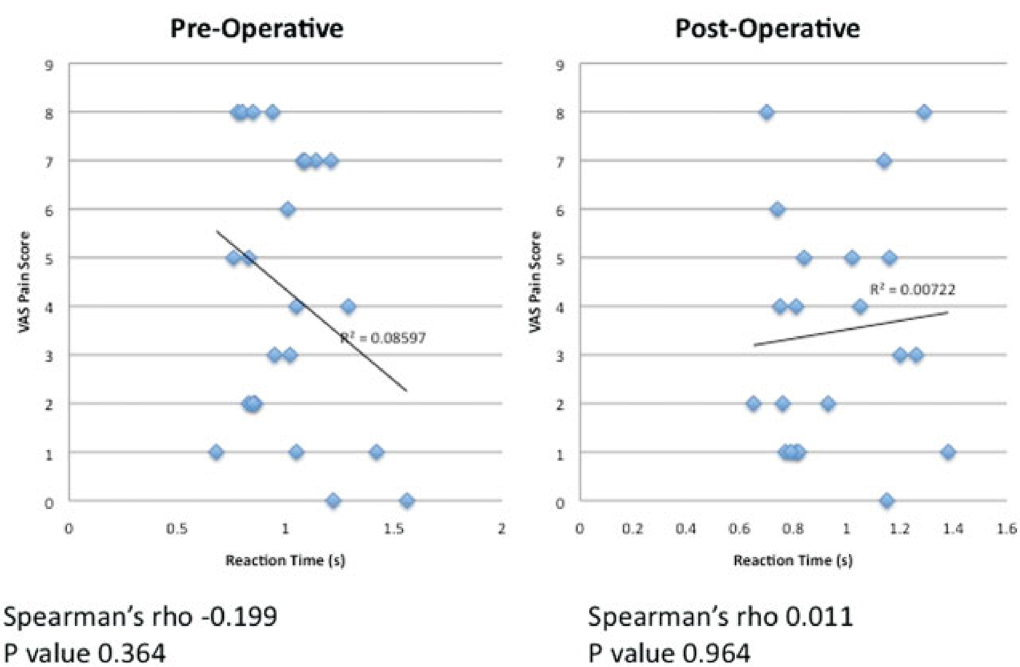

Fig. 5 Correlation of visual analog scale (VAS) pain scale and driver reaction time after lumbar spine surgery. We used Spearman correlation to compare reaction times and VAS scores of patients after lumbar spine surgery. There was no statistical relationship either before ($p = 0.364$) or after surgery ($p = 0.964$).

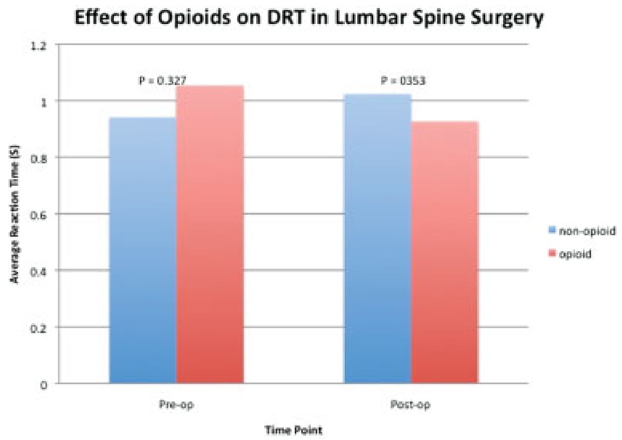

Fig. 6 Opioid use and driver reaction time (DRT) in lumbar spine surgery. Unpaired *t* testing was used to determine if there was a relationship between patient opioid use and driver reaction time in lumbar surgery. There was no relationship either preoperatively ($p = 0.327$) or postoperatively ($p = 0.353$) between opioid use and DRT.

and found that most patients reported no problem with driving at 6 weeks after surgery, which was the first postoperative time point recorded in their study.[14] In our study in contrast to lumbar surgery and in contrast to the results of Lechner's group, there was a slight trend toward an increased DRT after cervical surgery across all the groups. This is likely because our group was again more heterogeneous and included more patients with myelopathy and chronic pain who were less likely to have the immediate symptom resolution seen in the study of Lechner et al.[13] However, even in our group the overall difference between the mean preoperative and postoperative DRTs was only 0.031 seconds. At 70 mph, that difference would increase the total stopping distance by 3 feet. Given the small real-world effect this would have, it may be acceptable to allow some cervical patients who are not on narcotics to drive after the first postoperative visit, although surgeons should refrain from giving firm recommendations on this topic and factors including the disease severity must be considered.

DRT is one of many factors that affect a patient's ability to drive. It should be noted that though the medicolegal issues are outside the purview of this article, surgeons need to consider each patient individually and should probably refrain from giving firm recommendations. Although this study showed no significant effect on DRT from narcotic pain medication usage, we do not suggest any patient on narcotics return to driving, and furthermore, we did not have information about the amount of narcotic used by patients, so it remains very possible that patients using high doses of narcotic may have increased DRT. Also, the multilevel lumbar group did not trend toward a faster DRT like the other lumbar groups; likewise, the posterior cervical group showed the greatest increase in DRT postoperatively. Both these groups underwent more extensive surgeries than the other cohorts and likely had more pre- and postoperative pain. Pain may lead to reflex inhibition, which could be the root cause of the high pre- and postoperative DRT for the multilevel group.[17] In California, the DMV handbook notes the recommended DRT is 750 milliseconds but in foreign countries the recommended DRT varies from 700 milliseconds in Great Britain to 1,500 milliseconds in Germany. Although various models of driving simulators were used to establish those numbers and therefore they are not directly applicable to the results of this study, in our study the fusion and multilevel lumbar surgery groups and posterior cervical groups were subsets of patients with a mean DRT that approached that upper limit, so those patients should exercise extra caution.[4,16,18–20] For all drivers, it is probably wise to begin by practicing driving on short trips around their local neighborhood with a passenger who is available to drive.[3]

Weakness of our study include that we were unable to recruit any female controls and our controls were younger on average than our patients, both of which may contribute to the faster DRTs in the control group. Other potential weaknesses of this study include the small population size and the high rate of patient attrition in study participation after the first postoperative visit. Furthermore, our study population is relatively heterogenous, a fact that impacts the overall power of our study especially for the groups undergoing more extensive surgery, which may require longer postoperative recovery. Such subgroups were those receiving multilevel lumbar surgery, lumbar fusion, or posterior cervical surgery. In addition, our study only measured the speed at which the patient can compress a pedal and not the strength with which they are able to do so, and thus the results may not be generalizable to more real-world conditions. It is also cannot be ruled out that some improvement in the DRT may be secondary to learning by the patients. Moreover, it is possible that our follow-up period is too short to show the full effect on DRT of surgeries with longer recovery times, such as with lumbar fusion. To address these issues, we plan to recruit more patients for a future study with longer time periods in those subgroups with greater DRTs and likely longer postoperative recovery periods required. Specifically we plan to perform another study with increased participant numbers on patients undergoing lumbar fusion, multilevel lumbar surgery, and cervical surgery via the posterior approach as those groups had both pre- and postoperative DRTs closest to the recommended limit for safe driving and thus most require further study to elucidate when such patients may safely return to driving. The return to driving in real-world situations is vastly more complex than the driving simulator. Furthermore, the legal implications of driving are beyond the scope of this article. The DRT is a reasonable proxy for patients' ability to brake in an emergency, but it must be remembered that it does not address the many other aspects of real-world driving like baseline functional status and the patients' ability to effectively maneuver within their seats to adequately observe their environments—all of which impact each individual patient's ability to return safely to driving.

In summary, for patients who have received either cervical or lumbar surgery, there is no measurable change in the DRT between the preoperative visit and the first postoperative visit. The one exception to this is single-level lumbar surgery, in which the DRT is significantly improved at the first operative visit. This is in contrast to our hypothesis that patients' DRTs would be elevated at 2 to 3 weeks postoperatively. We believe that these data indicate that some spinal patients, especially those having single-level lumbar surgery and those who have good baseline functional status, may be able to return to driving after their first postoperative visit. Our data may be useful in developing guidelines regarding return to driving, although further study is needed.

Disclosures

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