Driving reaction time before and after anterior cervical fusion for disc herniation: a preliminary study

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Abstract

Purpose Reduced driving reaction time (DRT) has already been studied in context with lumbar disc surgeries. Data on whether cervical spine pathologies impair driving abilities are still lacking. In addition, no return-to-driving recommendations after anterior cervical fusion procedures have been published. Therefore, we assessed DRT before and after anterior cervical discectomy and fusion.

Methods We performed a prospective study with 12 patients (mean age 47.2 years; female 7, male 5). DRT as well as arm and neck pain were evaluated before surgery, on the day before discharge from hospital and at the 4–6-week follow-up examinations. 31 healthy subjects were tested for DRT as a control group.

Results All patients showed significant improvement in DRT in the longitudinal course ($p < 0.05$). DRT was 601 ms (median, IQR: 63) before surgery, which was reduced to 580 ms (median, IQR: 112) on the day before discharge from hospital and to 532 ms (median, IQR: 48) at follow-up examination. Control subjects had a driving reaction time of 487 ms (median, IQR: 116), which differed significantly from that of patients at all three testing times ($p < 0.05$). VAS for arm and neck pain showed significant improvement ($p < 0.05$).

Conclusion The present results show a positive effect of anterior cervical discectomy and fusion on driving safety. Based on our data we state that it appears to be safe to

resume driving after discharge from hospital. However, patients scheduled to undergo anterior cervical discectomy and fusion should be informed about increased DRT as compared to healthy individuals.

Keywords Anterior cervical fusion · Cervical discectomy · Cervical disc herniation · Driving reaction time · Driving safety

Introduction

Mobility, like the ability to drive a car, is one of the key factors in quality of life for patients. Patients planned for anterior cervical discectomy and fusion (ACDF) frequently ask when they will be allowed to drive a car again after surgery. Driving reaction time (DRT) is one of the key factors of driving safety [1]. Several reports have investigated clinical outcome, cost effectiveness and complications after ACDF [2]. However, no data regarding driving safety or return-to-driving recommendations after ACDF exist. DRT has been evaluated before and after surgery for lumbar disc herniation [3]. Those authors identified a positive effect of surgery on DRT for patients with sciatica as well as for patients with neurological impairment caused by disc herniation.

Although cervical disc herniation without myelopathy does not directly influence the lower extremity, DRT may be prolonged because of reflex inhibition caused by pain [4]. In general, spinal pathologies such as radiculopathy [1] and degenerative spinal disease [5] may cause a delay in neural signal transfer, and this can result in a longer DRT. The aim of the present study was to evaluate whether DRT is impaired in cervical disc herniation and, furthermore, to investigate the effect of cervical disc herniation on DRT

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before and after ACDF. The obtained data were compared with those for a group of asymptomatic healthy individuals.

Materials

Twelve patients with cervical radiculopathy caused by a radiologically verified single- or double-level cervical disc disease were recruited for the current study.

Inclusion criteria were symptomatic single- or double-level cervical disc disease presenting with radiculopathy, age of at least 18 years, and failure of non-surgical treatment that consisted of rest, anti-inflammatory medication and physical therapy.

Exclusion criteria consisted of symptomatic multi-level cervical degenerative disc disease, extensive compressive pathology requiring substantial resection of adjacent vertebral bodies, primarily posterior degenerative changes and neural compromise, coexisting neurological disorders (e.g. multiple sclerosis), acute trauma, cauda equina syndrome, coexisting diabetes mellitus, positive tumor anamnesis, positive alcohol anamnesis, recreational drug use, pathologic or infectious etiology, spondylolisthesis as well as scoliosis. Three test series as well as clinical examinations were performed. The first test was performed preoperatively (pre-op) one day before surgery, the second test before hospital discharge (post-op) and the third test at follow-up examination (FU) 4–6 weeks after ACDF.

On each test occasion arm and neck pain were evaluated on a Visual Analogue Scale (VAS) ranging from 0 for no pain to 10 for very severe pain. Neck and arm pain were assessed under routine conditions and during DRT testing. Driving frequency (never, once a month, once a week, daily) and intake of analgesics were assessed on each test occasion. All included patients had a valid driving licence. The patients were assessed for motor deficit on the Medical Research Council Scale for Assessment of Muscle Power.

The control group consisted of 31 healthy individuals with a valid driving licence, at least 10 years of driving experience and no history of spinal pathology.

The study was approved by the local ethics committee. Furthermore, all patients gave informed consent prior to participation.

Procedure

DRT tests were performed with a validated custom-built car simulator [6, 10]. The simulator consisted of an adjustable car seat fixed on a frame with hanging pedals (Fig. 1). The position of the car seat was adjustable (seat inclination, head rest and seat–pedal distance), to simulate the patient's favourite position in a car [3]. In front of the

Fig. 1 Custom-made car simulator for measuring driving reaction time. *Top right* external box containing the logic gate electronics, clock, green and red lamps

patient a box containing the electric logic circuit, a red and green signal light was placed. If the patient fully depressed the accelerator pedal the green signal light lit up. After an interval of 5–10 s, the observer pushed an external trigger, invisible to the patient, which activated the red signal light and the electronic clock. The patients were informed to push the brake pedal as quickly as possible with the right leg when the red signal light lit up, while the left leg stayed on the clutch pedal. The time period from the flash of the red signal light till the application of the brake was measured in milliseconds (ms). Each patient performed three dry runs. DRT was measured ten times at an interval of 5–10 s between each measurement. These DRTs were included in statistical analysis. All patients were instructed according to the same study protocol. Reproducibility tests were not performed, because we refer to previously published study protocols [6].

Statistical analysis

Data were processed using the Statistical Package for Social Sciences (SPSS17 Norusis/SPSS Inc., Chicago, IL, USA). Driving reaction times were not normally distributed and therefore regarded as ordinal variables. Median (Md) and interquartile ranges (IQR) were used as descriptive statistics. To compare DRT values DRT means (10 measurements) were calculated at each test occasion for each patient. For inferential statistics, the Friedman test was used to test for longitudinal differences in DRT. p value < 0.05 was defined as statistically significant. In the case of significant results, Wilcoxon tests were performed for post hoc analysis (pre-/post-op comparison, post-op/FU comparison); p values < 0.025 were defined as statistically significant. The Spearman Rho coefficient was used to identify correlations (0.0–0.4 no correlation;

0.4–0.7 moderate correlation; 0.7–1.0 strong correlation). Cross-sectional testing (independent variables) for the influence of pain medication on DRT was performed with the Mann–Whitney *U* test at an alpha level of 0.05.

Results

Six patients had radiating pain in the right arm, while six patients had radiating pain in the left arm, caused by cervical disc herniation with a distinct nerve root compression confirmed by magnetic resonance imaging (MRI). None of the patients had a myelopathy. Clinical examination and DRT tests were performed one day before surgery (pre-op), 2.75 days [mean, SD (standard deviation): 1.0] after surgery for post-op testing, and 32.2 days (mean; SD: 3.7) after surgery for FU testing. In nine patients single-level ACDF was performed, while three patients underwent a double-level ACDF. None of the recruited patients had radiological or clinical signs of myelopathy. Demographic and baseline characteristics of the patients are shown in Table 1. No statistical difference was found between VAS for arm and neck pain under routine conditions and during testing. All patients showed a significant decrease in arm and neck pain between pre-op and post-op evaluation ($p < 0.05$). Neck pain showed significant improvement between post-op and FU examination ($p < 0.01$).

Longitudinal comparison revealed a significant decrease in DRT ($p = 0.001$). Post-hoc analyses at the alpha level of

0.025 showed significant differences between DRT post-op (Md: 579, IQR: 112) and DRT FU (Md: 529, IQR: 48) ($p = 0.005$). Between DRT pre-op (Md: 603, IQR: 63) and DRT post-op an improvement of 24 ms was seen ($p = 0.209$) (Fig. 2).

A moderate correlation was seen between arm pain before surgery and DRT pre-op ($\delta = 0.641$). Comparison of duration of pain before surgery and DRT revealed no correlation. Eleven of 12 patients drove their car daily, while one patient rarely used his car. No correlation was found between DRT at any measurement point and driving skills.

Comparison of preoperative and postoperative VAS scores for neck pain demonstrated a significant improvement ($p < 0.05$). VAS for arm pain showed a significant decrease immediately after surgery ($p < 0.05$).

Pain medication showed no influence on DRT at any of the three test occasions ($p > 0.05$). The study population had significantly prolonged DRTs on all test occasions as compared with DRTs from the healthy control group (487 ms).

Discussion

Patients frequently ask when they will be allowed to drive again after surgery. Although data on DRT before and after lumbar spine surgeries exist, the effect of cervical spine surgery on driving safety has not been previously studied.

The present results show significant improvement in DRT in the longitudinal comparison, indicating a positive effect of ACDF on DRT (Table 1). The decrease in DRT from pre-op to immediately postoperatively was 24 ms, and between post-op and the FU examination 50 ms.

Table 1 Comparison of demographic data and descriptive statistics for DRT and VAS before and after anterior cervical discectomy and fusion

	ACDF patients	Controls
Age [mean (SD)] (years)	47.7 (12.2)	52.0 (7.7)
Female (<i>n</i>)	7	19
Male (<i>n</i>)	5	12
Herniation level		
C4/C5	2	
C6/C7	4	
C7/C8	6	
VAS Neck pre-op	6 (3.75)	
VAS Neck post-op	3 (4.75)	
VAS Neck FU	0 (2.5)	
VAS Arm pre-op	6 (3.75)	
VAS Arm post-op	1 (3)	
VAS Arm FU	0 (0)	
DRT pre-op (ms)	603 (63)	487 (116)
DRT post-op (ms)	579 (112)	
DRT FU (ms)	529 (48)	

Data are presented as median (IQR)

Fig. 2 Box plots showing driving reaction time for preoperative (pre-op), postoperative (post-op), and follow-up (FU) measurements

Similar DRT improvement was shown for patients after surgery for lumbar disc herniation in the longitudinal comparison. However, Thaler et al. [3] showed a significant DRT reduction in patients with lumbar disc herniation immediately after surgery. In the present study a significant decrease was found between pre-op and FU test. The difference might be because lumbar disc herniation directly affects the lower extremity with radiating pain or paresis, or because the patient size in our study was very small.

The similarity in DRT improvement can most likely be attributed to several factors. Several additional parameters such as neurological reaction time and foot transfer time influenced by pain may affect DRT and act as confounders [7]. Pain influencing reflex inhibition seems to be one of the most important cofounders [4]. These factors prolong the foot transfer time on the pedal and also generate sufficient force on the brake pedal [7].

Pain seems to have an influence on monitoring visual acuity, which is an important aspect in personal reaction to visual stimuli. In general, spinal pathologies such as radiculopathy [1] and degenerative spinal disease [5] may cause a delay in neural signal transfer, and this can result in a longer DRT. Although only the right leg is involved in a braking procedure, several reports demonstrated a prolonged DRT before and after surgical interventions of the left lower extremity in total hip replacement [6, 8], total knee replacement [7, 9, 10], anterior cruciate ligament reconstruction [11, 12], selective nerve root blocks [1] and lumbar disc surgery [3]. Liebensteiner et al. [5] showed an influence of primary lumbar fusion on DRT in patients with chronic lumbar back pain. Scott et al. [13] concluded that pain influences muscle performance and therefore DRT. These findings underline the hypothesis that pain prolongs DRT.

Thaler et al. [3] investigated DRT in patients with radiculopathy before and after lumbar disc surgery. They found a significant increase in DRT immediately after surgery and concluded that driving appears to be safe after discharge from hospital. Because of the lack of thresholds for safe DRT, those studies based their recommendations for a driving abstinence on the difference from preprocedure DRT values.

Our patient sample showed significantly longer DRTs on all three test occasions as compared to the control group consisting of healthy individuals.

One limitation on the current study is the fact that we tested DRT only three times. The second limitation is that the patient sample is small ($n = 12$). However, most studies investigating DRT before and after surgeries have similar numbers of individual tested [1, 5]. In addition, in the present study statistic significant differences were seen even with this small sample size indicating a very high effect of the surgery on DRT. A third shortcoming is that we did not investigate DRT in different age groups. Future studies should be performed with more follow up

examinations, larger patient samples investigating DRT in different age groups. More follow-up examinations would provide additional information on postoperative DRT course. Another shortcoming is that we did not investigate the difference between the two DRT sub-periods: reaction time and movement time. However, these two components are of less importance in daily traffic when a car has to be stopped quickly.

In the present study pain medication was not seen to have a significant influence on DRT. Similar findings have been made by several studies showing that opioids and other pain medication have no effect on DRT [5, 14, 15], thus confirming the results found in the present study.

Driving impairment has been reported for patients with acute administration of opioids or an increase in opioid dosage. However, the impairment diminishes with chronic, stable opioid usage [16]. Driving a car is a complex task requiring mental alertness and a variety of cognitive functions such as perception, attention, learning, memory, and decision making. It has been discussed that pain itself may lessen the ability to concentrate [17].

Significant differences in driving control between patients with chronic pain without pain medication and healthy controls have been reported. This difference in driving control corresponds to that observed in healthy volunteers after consuming alcohol up to a blood alcohol concentration of 0.08 %. This is above the legal limit for driving a car in many countries. It has been shown that with an alcohol level of 0.08 %, the estimated probability of causing an accident is approximately three times higher than for sober drivers [18]. Several studies have shown cognitive impairments on tasks in patients with chronic pain, particularly on measures assessing capacity of attention, processing speed, and psychomotor speed [19, 20]. These abilities are crucial in recognizing a stimulus (red light) and perform an adequate reaction caused by the stimulus (pushing the brake pedal). If pain itself impairs driving, efficient pain relief improves driving performance.

General anaesthesia should not have an effect on driving abilities, because the impairing impact of general anaesthesia disappears 24 h after surgery [7]. DRT is reported to also be influenced by several cofactors such as driver age, cognitive level, level of fatigue, alcohol and drug anamnesis as well as type and location of brake lights [21]. Therefore, for medico-legal reasons patients should be informed that their driving ability is impaired when suffering from cervical spine disease.

Conclusion

We demonstrated that DRT and thus driving safety is impaired by cervical disc pathologies. Our data reveal a

decrease of 24 ms immediately postoperatively and of 74 ms when comparing preoperative testing and follow-up examination, which differed significantly. Although no statistically significant reduction comparing pre-op and immediately post-op DRT regarding post hoc analysis could be shown, restrictions in patient mobility and therefore quality of life after surgery should be well considered. In the longitudinal follow up significant decreases of DRT were found. Due to the decrease in DRT, we conclude that it is safe to drive again after hospital discharge. However, all patients should be well informed that their DRT will be prolonged before and after ACDF as compared to that of healthy individuals.

Conflict of interest None.

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