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SYSTEMATIC REVIEW

When Can I Drive After Orthopaedic Surgery? A Systematic Review

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Abstract

Background Patients often ask their doctors when they can safely return to driving after orthopaedic injuries and procedures, but the data regarding this topic are diverse and sometimes conflicting. Some studies provide observer-reported outcome measures, such as brake response time or simulators, to estimate when patients can safely resume driving after surgery, and patient survey data describing when patients report a return to driving, but they do not all agree. We performed a systematic review and quality appraisal for available data regarding when patients are safe to resume driving after common orthopaedic surgeries and injuries affecting the ability to drive.

Questions/purposes Based on the available evidence, we sought to determine when patients can safely return to driving after (1) lower extremity orthopaedic surgery and injuries; (2) upper extremity orthopaedic surgery and injuries; and (3) spine surgery.

Methods A search was performed using PubMed and EMBASE®, with a list of 20 common orthopaedic procedures and the words "driving" and "brake". Selection criteria included any article that evaluated driver safety or time to driving after major orthopaedic surgery or immobilization using observer-reported outcome measures or survey data. A total of 446 articles were identified from the initial search, 48 of which met inclusion criteria; abstract-only publications and non-English-language articles were not included. The evidence base includes data for driving safety on foot, ankle, spine, and leg injuries, knee and shoulder arthroscopy, hip and knee arthroplasty, carpal tunnel surgery, and extremity immobilization. Thirty-four of the articles used observer-reported outcome measures such as total brake time, brake response time, driving simulator, and standardized driving track results, whereas the remaining 14 used survey data.

Results Observer-reported outcome measures of total brake time, brake response time, and brake force postoperatively suggested patients reached presurgical norms 4 weeks after right-sided procedures such as TKA, THA, and ACL reconstruction and approximately 1 week after left-sided TKA and THA. The collected survey data suggest patients resumed driving 1 month after right-sided and left-sided TKAs. Patients who had THA reported returning to driving between 6 days and 3 months postoperatively. Observer-reported outcome measures showed that patients' driving abilities often are impaired when wearing an immobilizing cast above or below the elbow or a shoulder sling on their dominant arm. Patients reported a return to

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driving on average 2 months after rotator cuff repair procedures and approximately 1–3 months postoperatively for total shoulder arthroplasties. Most patients with spine surgery had normal brake response times at the time of hospital discharge. Patients reported driving 6 weeks after total disc arthroplasty and anterior cervical discectomy and fusion procedures.

Conclusions The available evidence provides a best-case scenario for when patients can return to driving. It is important for observer-reported outcome measures to have normalized before a patient can consider driving, but other factors such as strength, ROM, and use of opioid analgesics need to be considered. This review can provide a guideline for when physicians can begin to consider evaluating these other factors and discussing a return to driving with patients. Survey data suggest that patients are returning to driving before observer-reported outcome measures have normalized, indicating that physicians should tell patients to wait longer before driving. Further research is needed to correlate observer-reported outcome measures with adverse events, such as motor vehicle accidents, and clinical tests that can be performed in the office.

Level of Evidence Level III, therapeutic study

Introduction

A frequently asked question in orthopaedic clinics is "when can I drive?" The National Highway Traffic Safety Administration has recommendations regarding returning to driving with certain medical conditions and procedures, but these recommendations have not been proven to reduce crash risk and are not intended for use as formal practice guidelines [62]. There currently are no standard guidelines indicating when a patient can resume driving after orthopaedic surgery. Fractures, arthroscopy, arthroplasty, and limb immobilization can affect a patient's ability to drive safely, and all may do so to different degrees. Patients desire to quickly resume driving, as the inability to drive can be disruptive, whereas physicians often wish for patients to temporarily hold off driving, allowing time for the patients to heal, and preventing them from getting in accidents because of their current condition.

Several review articles [8, 18, 40, 52] have discussed the issue of driving after orthopaedic surgery and injuries. These articles discussed observer-reported outcome measures such as brake response time, brake force, and simulators that have been used to evaluate driving ability. Procedures such as TKA have a substantial effect on brake response time, but the postoperative duration of this effect was reported to range from as brief as 10 days to as long as 8 weeks [40]. Similar discrepancies exist for other procedures such as THA, with one study [39] suggesting a return to driving at 6 weeks whereas others recommended 8 weeks [15, 18]. To our knowledge, these controversies have not been approached using a systematic review, and the discussion of driving after orthopaedic surgery can be enhanced with inclusion of postoperative patient survey data and quality appraisal of any relevant articles.

To provide surgeons assistance in handling the issue of driving after orthopaedic procedures and injuries, we systematically reviewed the current literature to answer the following questions: (1) When can patients safely return to driving after lower extremity orthopaedic surgery and injuries? (2) When can patients safely return to driving after upper extremity orthopaedic surgery and injuries? (3) When can patients safely return to driving after spine surgery?

Search Strategy and Criteria

To answer our research questions, we identified the 20 most-common orthopaedic procedures [16], to be separated by upper extremity, lower extremity, and spine categories. Two authors (KJD, AJS) independently performed searches of PubMed and EMBASE® from inception to July 2015 for any eligible articles using the words "driving" and "brake" combined with each of the previously identified orthopaedic procedures. We searched a combination of key words including the search terms to capture all relevant articles. For example, we searched "knee arthroscopy and meniscectomy driving" and "knee arthroscopy driving", then repeated but substituting the word "brake" for "driving". Inclusion criteria were any English-language article that primarily evaluated driver safety or time to return to driving after major orthopaedic surgery and immobilization. Studies evaluating either observer-reported outcome measures of driver function and/or survey data were eligible for inclusion. Observer-reported outcome measures were defined as a measurement that could be evaluated and compared, such as brake response time or a score in a driving simulator. These measures are only one aspect of safe driving, and do not include other crucial factors such as the use of scheduled narcotics. All references from selected studies were reviewed to identify any additional articles that may have been overlooked or were not indexed in the electronic databases. Abstracts were not included in the review nor were non-English-language articles, articles that included nonorthopaedic procedures, and articles that did not specifically evaluate return to driving with either observer-reported outcome measures or survey data. Articles identified from references that discussed limb immobilization were included in our analysis.

Qualitative assessment of included studies was performed using the Methodological Index for Nonrandomized Studies (MINORS) checklist by one author (KJD) [56]. Noncomparative studies can receive an ideal score of 16 and comparative studies can receive an ideal score of 24.

Study Selection

An initial literature search yielded 446 references. Based on title and abstract, 381 were excluded as duplicates, abstracts, published in foreign languages, or irrelevant (Fig. 1). Of the 65 remaining articles, 38 met eligibility criteria for our study. Ten additional articles were identified after reviewing references, for a total of 48 articles (Table 1). Two of these articles discussed procedures that were not on our original list, one was not indexed in either database, one did not have driving as a primary focus, and the remaining six articles discussed driving with limb immobilization. Thirty-four articles had data relevant to our study Question 1 [1, 4, 5, 9, 10, 12, 13, 15, 19, 22, 23, 26–30, 34, 36, 37, 39, 41, 42, 45–50, 53, 55, 57, 60, 63, 64], eight had data relevant to Question 2 [2, 6, 7, 17, 20, 21, 43, 46], and seven had data relevant to Question 3 [3, 31, 32, 35, 54, 58, 59] (Table 1). The range of MINORS scores for comparative studies was 17 to 24, and the range for noncomparative studies was 11 to 15.

Data Collection

The following data from the included studies were collected and extracted by two authors (KJD, AJS) to spreadsheet software for analysis: (1) study details, including study design and level of evidence; (2) study population details, including the number of patients, the injury or surgical procedure performed, and laterality of the injury or procedure; (3) the method of evaluating returning to driving, including when assessments were made relative to injury or procedure, whether there was a control group, and (4) the results of the evaluation (Appendix 1).

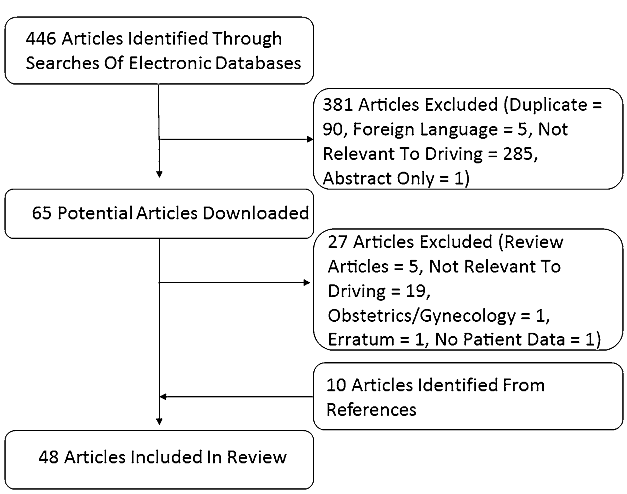

Fig. 1 The PRISMA flow diagram of our literature search is shown

Study Design and Populations

Brake response time was reported in 27 articles [3, 9, 10, 12, 15, 19, 22, 23, 26, 32, 35–37, 39, 41, 42, 47, 48, 50, 53, 54, 57–60, 63, 64]. Brake response time is the amount of time elapsed between the appearance of a stimulus and when contact was made with a brake pedal. Total brake time was reported in six articles [13, 26, 28, 30, 48, 60]. Total brake time is the amount of time elapsed between the appearance of a stimulus and when a brake pedal is fully depressed. Brake force was reported in four articles [30, 39, 60, 64]. Upper extremity immobilization studies used driving abilities score, simulators, and standardized tracks [6, 7, 20, 21]. The driving score reflected specific activities of driving such as steering and signaling [6]. The driving simulators evaluated participants' ability to avoid hazards and collisions. Two studies included data regarding a stepping test and a standing test [22, 47]. The stepping test counts how many times a patient can plant his or her foot on alternating sides of an obstacle in 10 seconds. The standing test counts how many times a patient can transition between a seated position and a standing position in 10 seconds. One article included a different type of step test that involved maintaining balance on the involved limb while using the contralateral limb to step on and off a 15-cm step as quickly as possible [9]. Survey data of when patients reported return to driving were published in 14 articles [1, 2, 4, 5, 17, 27, 29, 31, 34, 43, 45, 46, 49, 55].

Table 1. Description of included articles

Number of articles	Description
3	Ankle injuries
2	Foot injuries
1	Articular, femur, and tibial shaft fractures
5	Knee arthroscopy
9	Knee arthroplasty
9	THA
1	Hip, shoulder, and knee arthroplasty
4	Lower extremity immobilization
2	Shoulder arthroscopy
1	Carpal tunnel surgery
4	Upper extremity immobilization
7	Spine surgery

Results

Safely Driving after Lower Extremity Orthopaedic Injuries and Procedures

Observer-reported Outcome Measures

Patients with a right ankle fracture treated operatively had total brake times not significantly different from those of controls at 9 weeks postoperatively [13] and brake response times back to normal 1 week after cast removal [64] (Table 2). Patients with a right first metatarsal osteotomy had significantly improved brake response times at 6 weeks [26]. Patients with right articular fractures (plateau, pilon, calcaneus, and acetabulum) and those with right tibial shaft or femur fractures had significantly improved brake response times 6 weeks after initiation of weightbearing therapy [12]. Patients with ACL reconstruction had normal brake response times 4 to 6 weeks after surgery on the right [19, 47] and 2 weeks after surgery on the left [47]. There also are data showing that clinical tests, such as the stepping and standing tests, were strongly correlated with observer-reported outcome measures of driving ability after ACL reconstruction [47]. Patients with smaller arthroscopic procedures such as partial meniscectomies, chondroplasties, and diagnostic arthroscopies, had elevated brake response times for at least 1 week after surgery [22]. A similar correlation was found in these patients between stepping and standing tests and brake response time [22]. Patients with a right TKA had normal brake response times and total brake times 2 to 8 weeks postoperatively [9, 28, 36, 37, 42, 50, 57] and normal brake response times 0 to 3 weeks after a left TKA [36, 37, 41, 50, 57]. Data showed that a step test was the best predictor of safety when correlated with total brake time after TKA [28]. Patients with THAs had normal brake response times, total brake times, and brake forces 2 to 8 weeks after right-sided procedures [15, 23, 30, 39, 53] and 1 to 8 weeks after left-sided procedures [15, 30, 39]. Driving measures such as brake response time, total brake time, and brake force were significantly impaired when a driver wore a right lower-extremity hard cast, aerated orthosis, controlled ankle-motion cast, short leg cast, above- or below-knee plaster cast, or ROM-restricting brace [10, 48, 60, 63].

Survey Measures

Patients with operative Achilles tendon repair reported a return to driving at an average of 49 days, which correlated with full weightbearing status [29] (Table 3). Patients with a 5th metatarsal avulsion fracture reported a return to driving at 6 weeks when treated with a walking boot and 12 weeks after injury when treated with a short leg cast [55]. After arthroscopic procedures such as meniscectomies, chondroplasties, and diagnostic arthroscopies, patients reported returning to driving between 1 day and 3 weeks after surgery [4, 34]. After right TKA, 48% of patients were driving within 1 month compared with 57% who had a left TKA [27], whereas a survey with no distinction of laterality showed 25% of patients driving within 1 month and an additional 71% driving 1 to 3 months postoperatively [46]. Patients who had THAs reported driving as early as 6 days and as late as 3 months postoperatively [1, 5, 45, 46, 49].

Safely Driving after Upper Extremity Orthopaedic Injuries and Procedures

Observer-reported Outcome Measures

Driving simulators and standardized tracks showed that driving ability is impaired when patients wear a right or left scaphoid and Bennett's cast, above- or below-elbow immobilization, or a shoulder sling on the dominant arm [6, 7, 20, 21] (Table 4). No articles that evaluated observer-reported outcome measures after upper extremity surgery matched our search criteria.

Survey Measures

Patients reported returning to driving after rotator cuff repair between the same day to 4 months postoperatively [17] (Table 5). After right or left arthroscopic subacromial decompression, patients reported returning to driving 1 month, on average, after surgery [43]. Thirty-nine percent of patients with right or left total shoulder arthroplasty resumed driving within 1 month and another 55% resumed driving within 1 to 3 months [46]. Patients with open carpal tunnel surgery reported returning to driving 9 days, on average, after surgery [2].

Safely Driving after Spine Surgery

Observer-reported Outcome Measures

Patients with lumbar discectomy for radiculopathies [58], cervical and lumbar decompression and/or fusion [35, 54], and standard posterior sequestrectomy or subtotal discectomy [59] did not have an elevated brake response time at the time of discharge from the hospital (Table 6). However, patients with anterior cervical fusion had elevated brake response time compared with healthy control subjects [32]. Patients with radiculopathy and selective nerve

Table 2. Objective studies evaluating driving after lower extremity injuries and procedures

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Recommendations about driving	Sample size	Assessments	Comparison	LOE	MINORS score
Egol et al. [13]	2003	Ankle fracture, operative	TBT	BRT: control, 1079 ms; 6-week postoperative, 1172 ms; 9 weeks, 1160 ms	R, 9 weeks	R, 31	6, 9, 12 weeks postoperative	Healthy volunteers	II	19
Yousri and Jackson [64]	2015	Ankle fracture	BRT, BF	BF: 34.4 kg with injured leg, 35 kg with contralateral; BRT: 790 ms with injured leg, 860 ms in contralateral.	R: 7.8 days after cast removal	R 12	Average 7.8 days after cast removal	R to L	II	18
Holt et al. [26]	2008	First metatarsal osteotomy	BRT, TBT	TBT: preoperative, 806 ms; 2 weeks, 850 ms; 6 weeks, 684 ms	R: 6 weeks	R 28	Preoperative, 2 and 6 weeks postoperative	Preoperative, healthy volunteers	II	20
Egol et al. [12]	2008	Femur, tibial shaft fractures, operative	BRT	BRT: control, 302 ms; 6 weeks postoperative, 444 ms; 9 weeks, 377 ms; 12 weeks, 359 ms	R: 12 weeks postoperative (6 weeks after initiation of weightbearing)	R 22	6, 9, 12 weeks postoperative	Healthy volunteers	II	19
Egol et al. [12]	2008	Articular fractures, operative	BRT	BRT: control, 302 ms; 6 weeks postoperative, 412 ms; 9 weeks, 343 ms; 18 weeks 339 ms	R: 18 weeks postoperative (6 weeks after initiation of weightbearing)	R 35	12, 15, 18 weeks postoperative	Healthy volunteers	II	19
Nguyen et al. [47]	2000	ACL reconstruction	BRT	R BRT: preoperative, 738 ms; 6 weeks postoperative, 733 ms; L BRT: preoperative, 662 ms; 2 weeks, 660 ms	R: 6 weeks; L: 2 weeks	R 36, L 37	Preoperative, 2, 4, 6, 8 weeks postoperative	Preoperative, healthy volunteers	II	19
Gotlin et al. [19]	2000	ACL reconstruc-tion	BRT	BRT reached the 50th percentile of national BRT data 4 weeks postoperative	R: 4 to 6 weeks	R 14	2, 4, 6, 8, 10 weeks postoperative	Preoperative, healthy volunteers	II	20
Hau et al. [22]	2000	Partial meniscec-tomies, chondro-plasties, diagnostic arthros-copies	BRT	BRT: preoperative, 736 ms; 1 week postoperative, 920 ms; 4 weeks, 685 ms	R: at least 1 week	R 30	Preoperative, 1 and 4 weeks postoperative	Preoperative, healthy volunteers	II	22
Spalding et al. [57]	1994	TKA	BRT	BRT after L TKA remained constant through study, BRT after R TKA increased by > 50% at 4 weeks postoperative and returned to preoperative levels at 8 weeks	R: 8 weeks; L: no delay	R 20, L 9	Preoperative, 4, 6, 8, 10 weeks postoperative	Preoperative, healthy volunteers	II	19
Pierson et al. [50]	2003	TKA	BRT	BRT: no significant increase at 3 weeks, improved by 12.5% at 6 weeks and 17.5% at 9 weeks	R and L: as early as 3 weeks	R 25, L 19	Preoperative, 3, 6, 9 weeks postoperative	Preoperative, National BRT data	II	17
Marques et al. [41]	2008	TKA	BRT	BRT: preoperative, 430 ms; 10 days postoperative, 414 ms	L: 10 days	L 24	Preoperative, 10 days postoperative	Preoperative	III	11
Marques et al. [42]	2008	TKA	BRT	BRT: preoperative, 420 ms; 10 days postoperative, 458 ms; 30 days postoperative, 427 ms	R: 30 days	R 21	Preoperative, 10 days and 30 days postoperative	Preoperative	III	11
Liebensteiner et al. [36]	2010	TKA	BRT	R BRT: preoperative, 664 ms; immediately postoperative, 674 ms; 2 weeks, 643 ms; L BRT: preoperative, 632 ms; immediately postoperative, 642 ms; 2 weeks, 626 ms	R: 2 weeks; L: 2 weeks	R 13, L 18	Preoperative, postoperative, and at 2 weeks followup	Preoperative, healthy volunteers	II	21
Dalury et al. [9]	2011	TKA	BRT	BRT: preoperative, 530 ms; 4 weeks, 490 ms	R: 4 weeks	R 29	Preoperative, 4, 6, and 8 weeks postoperative	Preoperative	III	12

Table 2. continued

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Recommendations about driving	Sample size	Assessments	Comparison	LOE	MINORS score
Huang et al. [28]	2014	TKA	TBT	TBT at 50 km/hour: preoperative, 1.33 seconds; 2 weeks, 1.36 seconds; 4 weeks, 1.28 seconds	R: 4 weeks	R 14	Preoperative, 2, 4 weeks postoperative	Preoperative	III	11
Liebensteiner et al. 37]	2014	UKA	BRT	R BRT: preoperative, 786 ms; 1 week, 900 ms; 6 weeks 712 ms; L BRT: preoperative, 805 ms; 1 week, 743 ms	R: 6 weeks; L: no delay	R 21, L 22	Preoperative, 1, 6 weeks postoperative	Preoperative	III	15
Macdonald and Owen [39]	1988	THA	BRT, BF	R BRT: preoperative, 704 ms; 8 weeks 656 ms; 8 months, 591 ms; L BRT: preoperative, 594 ms; 8 weeks, 495 ms	R: 8+ weeks; L: 8 weeks	R 12, L 9	Preoperative, 8 weeks, 8 months postoperative	Preoperative, healthy volunteers	II	19
Ganz et al. [15]	2003	THA	BRT	R BRT: preoperative, 0.56 second; 1 week, 0.63 second; 4 weeks, 0.5 second; L BRT: preoperative, 0.55 second; 1 week, 0.53 second	R: 4–6 weeks; L: 1 week	R 52, L 38	Preoperative, 1, 4–6, 26, and 52 weeks postoperative	Preoperative, National DRT data	II	20
Jordan et al. [30]	2014	THA	TBT, BF	R TBT: preoperative, 626 ms; 6 weeks, 549 ms; R BF preoperative, 346 N; 6 weeks, 289 N; L TBT: preoperative, 541 ms; 8 days, 549 ms; L BF: preoperative, 423 N; 8 days, 368 N	R: 6 weeks; L: 8 days	R 20, L 20	Preoperative, 8 days, 6, 12, and 52 weeks postoperative	Preoperative	III	11
Ruel et al. [53]	2015	THA	BRT	BRT increased at 2 and 3 weeks compared with preoperative; BRT improved by 35 ms at 4 weeks	R: 4 weeks	R 90	Preoperative, 2, 3, 4 weeks postoperative	Preoperative	III	12
Hernandez et al. [23]	2015	THA	BRT	BRT: preoperative, 635 ms; 2 weeks, 576 ms	R: 2 weeks	R 38	Preoperative, 2, 4, and 6 weeks postoperative	Preoperative	III	14
Tremblay et al. [60]	2009	R lower extremity immobilization	BRT, TBT, BF	Control: BF, 294 pounds, BRT, 548 ms; cast: BF, 275 pounds, BRT, 571 ms; aerated orthosis: BF, 287 pounds, BRT, 581 ms	Significantly affected BRT and BF	48		Same volunteers without immobilization	II	22
Orr et al. [48]	2010	R lower extremity immobilization	BRT, TBT	TBT: control, 571 ms; controlled ankle motion, 675 ms; short leg cast, 640 ms; left foot adapter, 639 ms	Significantly affected TBT	35		Same volunteers without immobilization	II	24
Waton et al. [63]	2011	R lower extremity immobilization	BRT	Increase in stopping distance at 30 mph: 0°; brace, 1.4 m; below-knee plaster cast, 1.9 m; above- knee plaster cast, 2.8 m	Significantly affected BRT	23		Same volunteers without immobilization	II	22
Dammerer et al. [10]	2015	R lower extremity immobilization	BRT	BRT: control, 594 ms; ROM 0°–30°, 673 ms; ROM 0°–60°, 629 ms; ROM 0°–90°, 607 ms; ROM 20°–90°, 602 ms	ROM-restricting braces significantly impaired BRT	64		Same volunteers without immobilization	II	23

BRT = brake response time; R = right; L = left; TBT = total brake time; BF = brake force; DRT = driving reaction time; LOE = level of evidence; MINORS = Methodological Index for Nonrandomized Studies; MINORS score of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

Table 3. Patient-reported survey data of driving after lower extremity injuries and procedures

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Sample size	Assessments	LOE	MINORS Score
Jennings et al. [29]	2004	Achilles tendon repair*	Followup questions	Driving at 49 days	30	2, 6, 12 weeks, 3 years postoperative	IV	11
Shahid et al. [55]	2013	5th metatarsal avulsion fracture, walking boot*	Survey	Driving at 6 weeks	16	3, 6, 9, 12 weeks after injury	IV	12
Shahid et al. [55]	2013	5th metatarsal avulsion fracture, short leg cast*	Survey	Driving at 12 weeks	23	3, 6, 9, 12 weeks after injury	IV	12
Lewis et al. [34]	2011	Partial meniscectomies, chondroplasties, microfracture, diagnostic arthroscopy*	Survey	Driving 1 day to 3+ weeks postoperative	100	Followup appointment	IV	11
Argintar et al. [4]	2013	Partial meniscectomy, chondroplasty, débridement	Survey	R: Driving 1 week postoperative	R 69	Within 3 weeks postoperative	IV	12
Howell and Rogers [27]	2009	TKA	Survey	R: 48% drive within 4 weeks; L: 57% drive within 4 weeks	R 177, L 129	Preoperative, 4–5 weeks postoperative	IV	14
Muh et al. [46]	2012	TKA*	Survey	25% driving at < 1 month, 71% driving 1–3 months postoperative	258	Questionnaire sent at time of study	IV	14
Berger et al. [5]	2004	THA*	Followup questions	Driving at 6 days	100	Followup appointment	IV	14
Pagnano et al. [49]	2006	THA, staged bilateral*	Survey	Driving at 32–34 days	26	2, 8 weeks followup	IV	14
Meneghini and Smits [45]	2009	THA*	Survey	Driving at 23.7 days	24	Preoperative, 6 weeks, 3 and 6 months, 1 year postoperative	IV	12
Abbas and Waheed [1]	2011	THA	Survey	R: 79% driving at 6 weeks; L: 84% driving at 6 weeks	R 85, L 45	Survey after 6 weeks	IV	12
Muh et al. [46]	2012	THA*	Survey	19% driving at < 1 month, 77% driving at 1-3 months	196	Questionnaire sent at time of study	IV	14

* No distinction made between right- and left-sided injuries; R = right; L = left; LOE = level of evidence; MINORS = Methodological Index for Nonrandomized Studies; MINORS score is of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

Table 4. Observer-reported outcome measures evaluating driving following upper extremity injuries and procedures

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Recommendations about driving	Sample size	Comparison	LOE	MINORS Score
Blair et al. [6]	2002	Upper extremity immobilization (scaphoid, Bennett's, Colles')	Score given for driving abilities	Driving scores, Colles' L: 17, R: 18; scaphoid L: 13, R: 16; Bennett's L: 12, R: 16	L and R scaphoid and Bennett's casts significantly impair driving control; R and L Colles' have little effect	1	Same driver without immobilization	IV	12
Gregory et al. [20]	2009	R upper extremity immobilization (below elbow)	Circuits in a driving simulator	R limb immobilization had critically less distance from pedestrian before taking action t(7) = 1.94	Adversely affected responses to hazards, more prevalently with R	8	Same volunteers without immobilization	II	22
Chong et al. [7]	2010	R and L upper extremity immobilization (above- and below-elbow)	Standardized track and scoring system, survey of perceived difficulty	L: above-elbow splint added 22.2 seconds to time; below-elbow splint added 16.2 seconds	R: No significant difference; L: driving performance significantly degraded with splint	30	Same volunteers without immobilization	II	21
Hasan et al. [21]	2015	Upper extremity immobilization (shoulder sling)	Driving simulation	Total collisions with no sling: 36; total collisions with sling: 73	Immobilization of dominant arm decreases driving performance	21	Same volunteers without immobilization	II	23

LOE = level of evidence; R = right; L = left; MINORS = Methodological Index for Nonrandomized Studies; MINORS score is of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

root blocks had significantly elevated brake response times at 6 weeks with right nerve blocks but returned to baseline at 2 weeks after a left block [3].

Survey Measures

Patients with cervical disc arthroplasty or anterior cervical discectomy and fusion reported a return to driving, on average, 6 weeks after surgery [31] (Table 7).

Discussion

Patients frequently ask their orthopaedic surgeons when they can return to driving after various injuries and procedures. There are no standard guidelines that surgeons can use to advise patients. Orthopaedic injuries and operations can have a profound effect on the ability to drive. Pain and limitation in motion or function of upper and lower extremities can substantially affect driving safety. Several reviews on this topic have been published [8, 18, 40, 52], however in this study, we expanded on previously published reviews by performing a search in a systematic format, evaluating the quality of the studies, and including data from patient surveys. In addition, prior reviews focused primarily on one procedure or types of procedure, without compiling these data in a systematic format or recommendations. We attempted to answer the following research questions in this review: (1) When can patients safely return to driving after lower extremity orthopaedic surgery and injuries? (2) When can patients safely return to driving after upper extremity orthopaedic surgery and injuries? (3) When can patients safely return to driving after spine surgery?

As with many systematic reviews, our study was limited by the quality and quantity of the existing literature on the topic. The most frequently referenced observer-reported outcome measure for driving is the brake response time [3, 9, 10, 12, 15, 19, 22, 23, 26, 32, 35–37, 39, 41, 42, 47, 48, 50, 53, 54, 57–60, 63, 64]. Evaluations such as the brake response time are not perfect estimators of driving ability as there are many more obstacles and distractions on a road compared with a simulation. More importantly, these simulators represent best-case scenarios for when patients can safely return to driving. A patient should not return to driving before his or her brake response time has normalized, but there are other factors that also affect driving ability. A patient may have a normal brake response time 10 days after left TKA [41], but clearly is not ready for driving if he or she still is using a walker or still is taking narcotic analgesics. The studies reporting observer-reported outcome measures also had relatively small

Table 5. Patient-reported survey data of driving after upper extremity injuries and procedures

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Sample size	Assessments	LOE	MINORS score
McClelland et al. [43]	2005	Subacromial decompression*	Survey	Driving 28.9 days postoperative	68	Preoperative, 3 weeks, 3 months postoperative	IV	14
Muh et al. [46]	2012	Total shoulder arthroplasty*	Survey	39% driving < 1 month, 55% driving 1-3 months postoperative	31	Questionnaire sent at time of study	IV	14
Gholson et al. [17]	2015	Rotator cuff repair*	Survey	Driving same day to 4 months postoperative (median 2 months)	54	4 months postoperative	IV	13
Acharya and Auchincloss [2]	2005	Open carpal tunnel surgery	Survey	R and L: driving at 9 days	75	Preoperative and 3 months postoperative survey	IV	12

* No distinction made between right (R)- and left (L)-sided injuries; LOE = level of evidence; MINORS = Methodological Index for Non-randomized Studies; MINORS score is of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

sample sizes, which decreases their power to pick up on subtle differences that could have important clinical consequences. These limitations would underestimate the time it takes to be ready to drive again. Additionally, the studies assessed driver readiness based on observer-reported outcome measures or patient-reported timelines to return, but do not correlate these tests with real-world adverse events, such as motor vehicle accidents or driving infractions. The application of these data also is limited by practical reasons. It can be expensive and time consuming to construct a driving simulator or machine in every orthopaedic office to measure brake response time. Other limitations included variability in reporting, as not all studies specified laterality, which can affect driving particularly for lower extremity injuries and surgery. Studies used different measures of driver safety, and several used healthy volunteers. Physicians should exercise some caution using patient-survey data regarding return to driving. Reporting return to driving does not necessarily indicate that it is safe to do so. However, given the lack of definitive data on driving safety, sharing with patients when other people with a similar condition felt safe to resume driving can be useful information as long as the survey-reported return does not occur before the observer-reported outcome measures normalize. Many variables outside observer-reported outcome measures affect safe driving. Comorbidities such as sleep apnea [14], kidney disease, stroke [38], heart disease, arthritis in females, and the use of NSAIDs, angiotensin-converting enzyme inhibitors, and benzodiazepines [44], all are associated with substantially increased risk of motor vehicle crashes and difficulty driving; conditions such as obesity [65] are associated with increased risk of fatality in a motor vehicle crash. The use of a cellular telephone quadruples the risk of collision [51]. These variables were not evaluated in published studies regarding driving safety after orthopaedic procedures, which is an additional limitation to our study.

The brake response time, total brake time, brake force, and patient-reported data were used to evaluate return to driving after lower extremity injury and orthopaedic procedures. Observer-reported outcome measures indicate that patients return to preoperative levels approximately 1 month after right ACL reconstruction, TKA, and THA. Patients with left ACL reconstruction, THA, and TKA, and those with right-knee meniscectomies, chondroplasties, and diagnostic arthroplasties reached preoperative observer-reported outcome measures 1 week after surgery. Although a patient may reach preoperative levels of observer-reported outcome measures or ones comparable to levels of healthy volunteers, it does not mean that the patient is absolutely safe to drive, as all of the other factors that affect driving safety need to be considered. Evaluation of braking function after foot, ankle, and lower extremity fractures suggested that patients return to preoperative or control ranges 6 weeks after right first metatarsal osteotomy, 9 weeks after right ankle fracture treated operatively, and 18 weeks after operative treatment of right plateau, pilon, calcaneous, and acetabulum articular fractures. It is not safe for patients with most forms of right lower extremity immobilization to drive. Clinical tests such as the stepping and standing tests correlated with measurements of brake function after TKA, ACL reconstruction, and other arthroscopic knee procedures [9, 22, 47]. Using clinical tests to evaluate driving ability is a simple and cost-effective way to help physicians provide patients with driving advice. Further research is needed to validate these tests for a broader spectrum of surgeries.

Upper extremity procedures and immobilizations were evaluated with simulators and patient-reported return to driving. Tests of braking function are not applicable with

Table 6. Observer-reported outcome measures evaluating driving after spine surgery

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Recommendations about driving	Sample Size	Assessments	Comparison	LOE	MINORS Score
Al-khayer et al. [3]	2008	Radiculopathy and selective nerve root block	BRT	R: BRT preoperative, 521 ms. 6 weeks postoperative, 564 ms; L: BRT preoperative, 535 ms, 2 weeks postoperative, 534 ms	Be cautious driving immediately postoperative despite significantly elevated response times	R 10, L 10	Preoperative, immediately, 2, 6 weeks postoperative	Preoperative, healthy volunteers	II	22
Liebensteiner et al. [35]	2010	Lumbar fusion	BRT	Preoperative BRT, 685 ms; day before discharge, 728 ms; 3 months postoperative, 671 ms	Safe to drive after discharge from hospital	21	Preoperative, day before discharge, 3 months postoperative	Preoperative, healthy volunteers	II	21
Thaler et al. [58]	2012	Lumbar disc herniation repair	BRT	R: BRT preoperative, 664 ms; day of discharge, 605 ms; L: BRT preoperative, 675 ms; day of discharge, 638 ms	Safe to drive at discharge from hospital	R 23, L 23	Preoperative, day of discharge, 5 weeks postoperative	Preoperative, healthy volunteers	II	20
Lechner et al. [32]	2013	Anterior cervical fusion	BRT	BRT preoperative, 601 ms; day before discharge, 580 ms	Safe to drive at discharge from hospital	12	Preoperative, day before discharge, 4-6 weeks postoperative	Preoperative, healthy volunteers	II	18
Scott et al. [54]	2015	Lumbar and cervical - decompression and/or fusion	BRT	Cervical: BRT preoperative, 976 ms, 2 weeks postoperative, 1007 ms; lumbar: BRT preoperative, 1012 ms; 2 weeks postoperative, 953 ms	Cervical and lumbar: 2 weeks	Cervical 14, lumbar 23	Preoperative, 2–3, 6, 12 weeks postoperative	Preoperative, healthy volunteers	II	19
Thaler et al. [59]	2015	Standard posterior sequestrectomy or subtotal discectomy	BRT	R: BRT preoperative, 761 ms; immediate postoperative, 711 ms; L: BRT preoperative, 651 ms, immediate postoperative, 592 ms	Safe to drive at discharge from hospital	42	Preoperative, before discharge, 5 weeks postoperative	Preoperative, healthy volunteers	II	20

BRT = brake response time; R = right; L = left; LOE = level of evidence; MINORS = Methodological Index for Nonrandomized Studies; MINORS score is of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

Table 7. Patient-reported survey data of driving after spine surgery

Study	Year	Orthopaedic procedure	Method of evaluation	Results	Sample size	Assessments	LOE	MINORS score
Kelly et al. [31]	2013	Cervical disc arthroplasty or anterior cervical discectomy and fusion	Questionnaire	Cervical disc arthroplasty and anterior cervical discectomy and fusion: driving at 6 weeks	Cervical disc arthroplasty, 66; anterior cervical discectomy and fusion, 69	Preoperative, 6 weeks, 3, 6 months, 1, 2 years postoperative	IV	12

LOE = level of evidence; MINORS = Methodological Index for Nonrandomized Studies; MINORS score is of a possible 24 for comparative studies (level II) and 16 for noncomparative studies (levels III and IV).

upper extremity surgeries. Healthy patients driving on courses indicated that it is unsafe for patients with most forms of upper extremity immobilization to drive [6, 7, 20, 21]. A driving simulator that includes avoiding obstacles could be a better method of evaluating driving ability than an isolated evaluation of braking function, as there is more to driving and avoiding accidents than accounting for the time it takes to press the brake pedal. Additional research is needed to evaluate observer-reported outcome measures after upper extremity surgery and to identify the best method of evaluating driving readiness for these patients, potentially with a clinical test similar to the stepping and standing test used for lower extremity evaluations.

The brake response time and patient-reported return to driving were used to evaluate driving readiness after spine surgery and injuries. Observer-reported outcome measures indicate that patients with spinal procedures, such as lumbar or cervical fusion [32, 35], posterior sequestrectomy, subtotal discectomy [59], and radiculopathy and selective nerve root blocks [3] often have comparable values to those of their preoperative assessment at the time of discharge. Although the observer-reported outcome measures rapidly normalize after these procedures, physicians again are encouraged to consider all of the variables affecting safety when discussing returning to driving with patients. As described above, there also are practical limitations to using brake response time as a method of evaluating driving ability, and identifying clinical tests to evaluate readiness is an area for further studies.

Advances in evaluating patient safety in driving can be achieved through more widespread use of driving simulators and referral for official driving evaluation. Driving simulators are being used with increasing frequency in other medical fields, including evaluating patients who have had a stroke [25]. Lee et al. [33] found a sensitivity of 91.4% for driving simulators when evaluating elderly drivers with an accident history. This is an advantage over brake response time which is an intuitively highly specific test, as the inability to brake in an emergency will likely result in a crash, but potentially not as sensitive to the effect of some of the other comorbidities described above. We were unable to identify any data regarding sensitivity of the brake response time, which is another area for future research. Potentially these simulators could be used with greater frequency in the field of orthopaedics. As there can be medicolegal implications in advising patients about the safety of driving and limited-quality evidence, referring to an official driving evaluation by someone formally trained in making these assessments is an option. Official driving evaluations have been used to evaluate patients with Alzheimer's disease [24]. This option can be considered when multiple factors that affect safe driving are present in a patient.

Other Guidelines

Several administrative bodies also provide advice regarding safe driving. The use of opioid analgesics has been associated with an increased odds of unsafe driving [11], and the FDA advises all patients taking opioids not to drive or operate heavy machinery owing to drowsiness associated with these medications [61]. To safely drive, patients must have sufficient ROM in their neck, hands, shoulders, elbows, and ankles, and sufficient strength in these joints. The National Highway Traffic Safety Administration recommends that drivers have at least 4/5 strength in both upper extremities and right lower extremity to drive safely, with 4/5 strength defined as movement against gravity and some resistance [62].

Research regarding driving after orthopaedic surgery provides limited evidence about the best-case scenario for when patients ask about a return to driving. The observer-reported outcome measures used to evaluate driving readiness in these studies do not account for many important factors such as the use of opioid analgesics. A patient cannot return to driving before his or her brake response time has normalized, but this may not be the rate-limiting step on the path to recovery. This systematic review can be used as a guideline for when physicians can begin to consider evaluating if patients are ready to drive, along with an assessment of their strength, ROM, and medications (Table 8). Survey data show that patients often began driving before observer-reported outcome measures such as brake response time had normalized, which suggests that physicians should tell patients to wait longer before driving. Further research is needed to evaluate driving readiness after upper extremity surgery and to identify more clinical tests such as the stepping test and standing test that can be used to easily evaluate patients in the office setting. This can be done by identifying which observer-reported outcome measures correlate with adverse events such as motor vehicle accidents, then identifying a clinical test that is correlated with those observer-reported outcome measures. Returning to driving will not follow the same timeline for every patient, and ultimately patients must feel safe and ready to accept the risks of driving.

Table 8. Summary of timelines for observer-reported outcome measures to return to normal

Procedure	Timeline	Range of level of evidence
Right ankle fracture treated operatively	9 weeks postoperatively, or 1–2 weeks after cast removal	II
Right first metatarsal osteotomy	6 weeks postoperatively	II
Right femur and tibial shaft fractures treated operatively	12 weeks postoperatively, 6 weeks after initiation of weightbearing	II
Right plateau, pilon, calcaneous, and acetabulum articular fractures treated operatively	18 weeks postoperatively, 6 weeks after weightbearing	II
Right ACL reconstruction	4–6 weeks postoperatively	II
Left ACL reconstruction	2 weeks postoperatively	II
Right partial meniscectomies, chondroplasties, and diagnostic arthroscopies	1 week postoperatively	II
Right TKA	Most commonly 4 weeks, range of 2–8 weeks	II-III
Left TKA	0–3 weeks postoperatively	II-III
Right THA	Most commonly 4 weeks, range of 2–8 weeks	II-III
Left THA	1 week postoperatively	II-III
Radiculopathy and selective nerve root block	On hospital discharge	II
Lumbar and cervical fusion	On hospital discharge to 2 weeks	II
Standard posterior sequestrectomy/subtotal discectomy	On hospital discharge	II
Upper extremity immobilization	Not safe to drive with right or left scaphoid or Bennett's cast, or a shoulder sling on a patient's dominant arm. Above- and below-elbow splints can degrade driving performance.	II-IV
Lower extremity immobilization	Not safe to drive with a right hard cast, aerated orthosis, controlled ankle motion cast, short leg cast, below- and above-knee plaster cast, and ROM-restricting brace.	II

Appendix 1

Data collection form

1. Title
2. Author
3. Year
4. Journal
5. Body part
6. Orthopaedic procedure/injury
7. Method used to evaluate driving status/ability
8. Laterality
9. Results
10. Recommendation about driving
11. Sample size
12. Time at which assessments are performed
13. Comparison group
14. Level of evidence
15. MINORS score

MINORS = Methodological Index for Nonrandomized Studies

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