Driving after Distal Radius Fractures

SAFETY RESEARCH USING SIMULATION

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Abstract

Distal radius fractures (DRF) are a common orthopaedic injury, affecting over 640,000 people per year in the United States, and may account for 2.5% of emergency department visits. The treatment for DRF may be operative or non-operative, but both treatment options require a period of immobilization to allow healing. Pain, stiffness, and weakness are invariably present after this fracture and typically improve gradually over time.

One of the most common questions orthopedic surgeons are asked following a DRF is, "When can I drive?" Survey studies of physicians across multiple countries show a lack of standardization regarding recommendations, with little agreement regarding either criteria or timeframe for return to driving.

The pilot study aimed to evaluate the effect of DRF on safety of roadway users, particularly drivers in passenger vehicles, and provide valuable information to physicians in counseling their patients on return to safe driving. Subjects were evaluated at 2, 6, and 12 weeks post operatively. At post-op visits clinical data were obtained. These data included demographics (sex, age, hand dominance, laterality of DRF), splint usage, narcotic usage, and range of motion.

The driving simulation portion of the study occurred within 1 week of the post-operative clinic visits. The driving simulation used the miniSim research driving simulator. Each testing visit consisted of two separate driving scenarios preceded by a 5-minute practice drive. The first driving scenario included urban and rural driving environments that include curves and 90-degree turns. Some oncoming traffic was present, however, no traffic or pedestrian required the patient to change position or speed to avoid a crash. The second experimental drive involved a crash-imminent situation in which the driver had to rapidly change direction of travel to effectively respond to the event and avoid a crash.

Preliminary data from the first 4 fracture subjects and a control dataset were analyzed. No differences in standard deviation of lane position were observed under any normal driving

conditions. Average speed with respect to the speed limit in fractures compared with controls was significantly slower. However, fractures differed from controls in terms of the frequency and speed of steering inputs. Two weeks post-surgery, 3 out of 4 subjects failed to avoid the crash, with one not initiating a steering response and two not providing enough steering input to avoid the crash.

Preliminary results suggest patients 2 weeks after DRF volar plating are able to maintain lane position but with overall lower speed and fewer steering inputs, and with 75% (3 of 4) failing to avoid collision on a crash-avoidance task. With continued enrollment, a larger sample size will provide further insight into when DRF patients may safely return to driving.

1 Introduction

Distal radius fractures (DRF) are a common orthopaedic injury, affecting over 640,000 people per year in the United States [1], and may account for 2.5% of emergency department visits [2]. Although distal radius fractures affect people of all ages, they account for up to 18% of all fractures in patients over the age of 65 [3], and the incidence appears to be increasing over time [4]. The treatment for DRF may be operative or non-operative, but both treatment options require a period of immobilization to allow healing. Pain, stiffness, and weakness are invariably present after this fracture and typically improve gradually over time.

One of the most common questions we as orthopaedic surgeons are asked following a distal radius fracture is, "When can I drive?" Survey studies of physicians across multiple countries show a lack of standardization regarding recommendations, with little agreement regarding either criteria or timeframe for return to driving [5-7]. American Medical Association (AMA)/National Highway Traffic and Safety Administration (NHTSA) recommendations state that "older drivers" can return to driving on "demonstration of the necessary strength and range of motion" but do not provide guidelines regarding these. The U.S. Public Health Service (USPHS) recommends a performance examination if "impaired" but does not clarify who is considered impaired or when that impairment is considered resolved.

Further, there is little in the orthopaedic literature to guide us in making these recommendations. While braking time has been used to assess function and provide return-to-driving guidelines for lower-extremity injuries [8], a similar measure has not been described for the upper extremities. Sandvall and Friedrich in a recent review found that, while there is evidence to suggest that driving is affected by the wearing of upper-extremity immobilization devices, the studies published so far are quite limited and the driving assessments were performed on subjects who were not injured, significantly limiting their applicability [9].

2 Method

2.1 Participants

In order to be eligible for the study, participants had to be between the ages of 18 and 70, be a licensed driver who regularly drives more than 2000 miles per year, and have undergone surgery for an operative unilateral DRF with no additional injuries. Participants who were prone to significant motion sickness were excluded from the study. Four participants completed this study, 2 males and 2 females. Enrollment in the study was lower than originally anticipated with an original enrollment goal of 40 participants. Participants were recruited and consented by Dr. Caldwell and her staff after undergoing surgery. If all study procedures were completed, participants were paid a total of $250.

2.2 Procedure

2.2.1 Screening Visit

Study procedures began at the 2-week post-operative clinic appointment. Follow-up visits happen at 2, 6, and 12 weeks post operatively. These appointments are standard of care and happen regardless of participation in the study. At these post-op visits, clinical data were obtained. These data included demographics (sex, age, hand dominance, laterality of DRF), splint usage, narcotic usage, and range of motion. Prior to enrolling in the study, patients gave informed consent.

2.2.2 Study Visits

The driving simulation portion of the study occurred within 1 week of the post-operative clinic visits. The driving simulation used the miniSim research driving simulator. Each testing visit consisted of two separate driving scenarios preceded by a 5-minute practice drive. The first driving scenario of approximately 25 minutes included urban and rural driving environments that included curves and 90-degree turns. Some oncoming traffic was present; however, no traffic or pedestrian required the patient to change position or speed to avoid a crash.

The second experimental drive of approximately 5-7 minutes involved a crash-imminent situation in which the driver had to rapidly change direction of travel to effectively respond to the event and avoid a crash. Three crash-imminent situations that required a similar level of lateral response to safely avoid a collision were presented in random order, one at each visit. This scenario tested the participant's willingness and ability to change lateral position to avoid a crash.

Participants filled out a short survey before and after the driving simulation. The surveys asked participants to rate their confidence in their driving abilities both before and after the simulation and asked them to rate their workload (demand, frustration, pressure) and their performance after the simulation. A simulator realism survey was also given to participants. Total visit time was normally between 1 and 1.5 hours long.

2.3 Simulator Drives

Study drives consisted of both daytime and nighttime drives and took place in a variety of driving environments consisting of urban, rural, and highway driving. They can be divided into normal driving and emergency response driving.

2.3.1 Normal Driving

This included both urban and rural driving that required normal vehicle control including negotiation turns and curved roadways. This driving database is a subset of the drive developed for testing impaired driving associated with alcohol [10]. That study had three variations on the overall drive that were designed to be equivalent. This study used only the urban and rural drives. The interstate drive was excluded due to lesser steering demands.

2.3.1.1 Urban

The urban drive included normal steering, making a left turn, and navigating curves. It is illustrated in Figure 1.

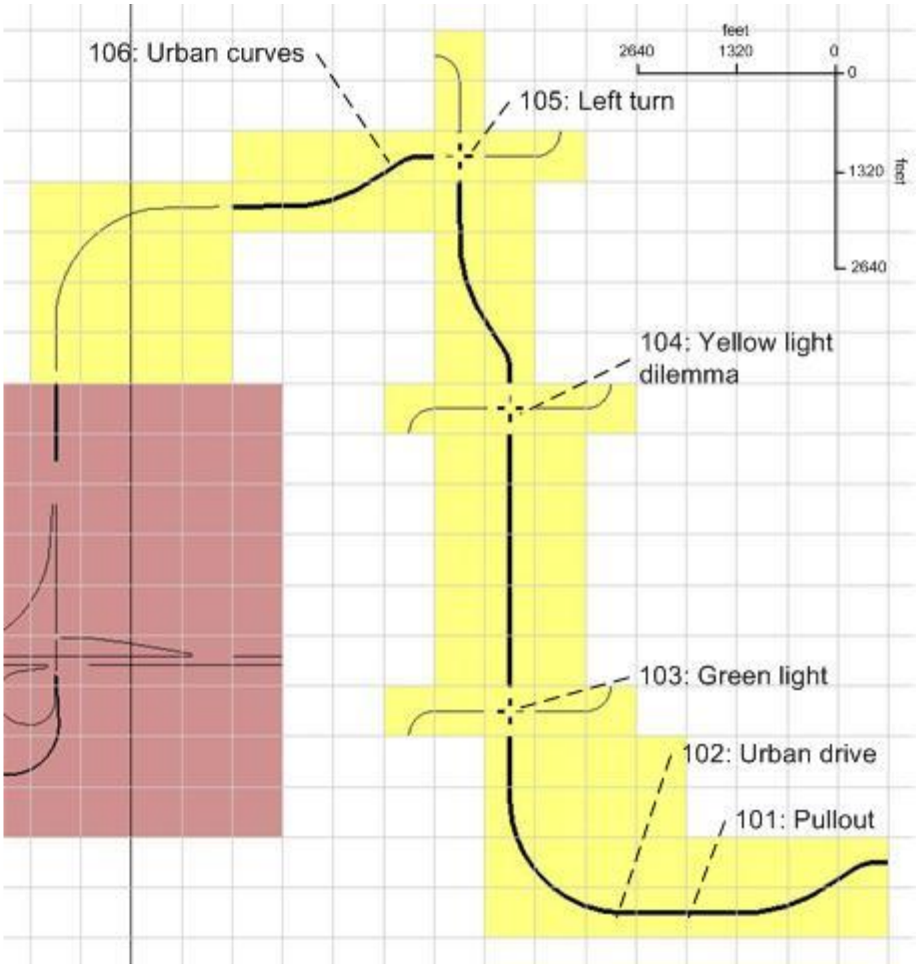

Figure 1. One of three variations of the urban driving route.

2.3.1.2 Rural

The rural drive includes normal steering, making a right hand turn, and navigating curves, including a tightening-radius curve. It is illustrated in Figure 2.

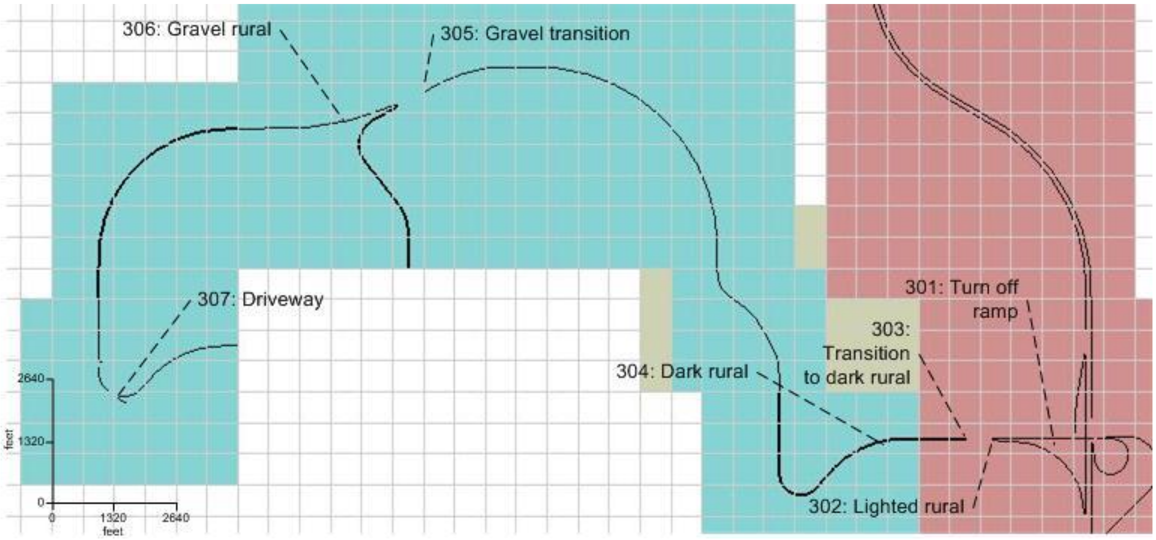

Figure 2. One of three variations of the rural driving route.

2.3.2 Emergency Response

These scenarios were designed as part of a series of studies [11] to test the ability of electronic stability control systems to prevent loss of control in the presence of rapid steering inputs. This subset was chosen to provide a range of situations that would not be likely to have a predictable threat from one visit to the next.

2.3.2.1 Avoid

In this scenario, the participant is following closely behind a cargo van in the far-right lane of a 4-lane road. The van's doors open suddenly, releasing a desk that falls directly into the participant's lane. The participant is given no warning before the event occurs and is supposed to try to avoid the desk by applying the brakes and swerving either to the left or the right. In order to make the maneuver and avoid the vehicle, the participant must turn the wheel hard left or hard right. This event is illustrated in Figure 3.

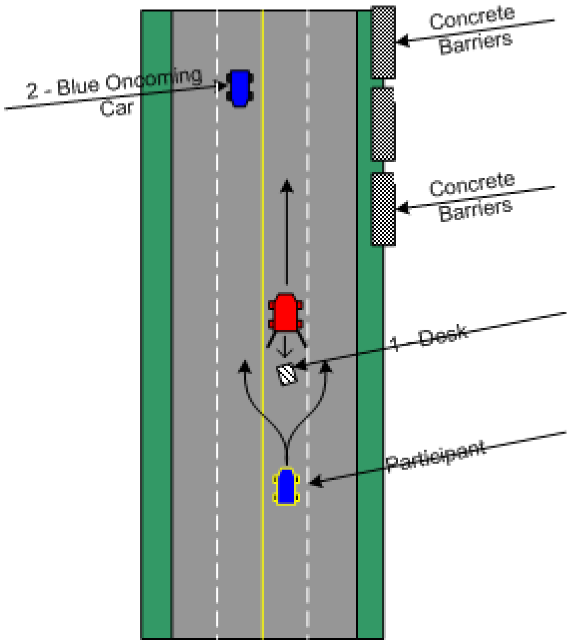

Figure 3. Scenario map for obstacle avoidance

2.3.2.2 Right Incursion

In this scenario, the participant is driving down a 2-lane road with oncoming traffic, and several semi-trucks are parked along the right side of the road. A vehicle that is hidden from view by one of the trucks pulls out at the last minute into the participant's lane. The participant must try to avoid the vehicle by applying the brakes and swerving either to the left or the right. In order to make the maneuver and avoid the vehicle, the participant must turn the wheel hard left or hard right. This event is illustrated in Figure 4.

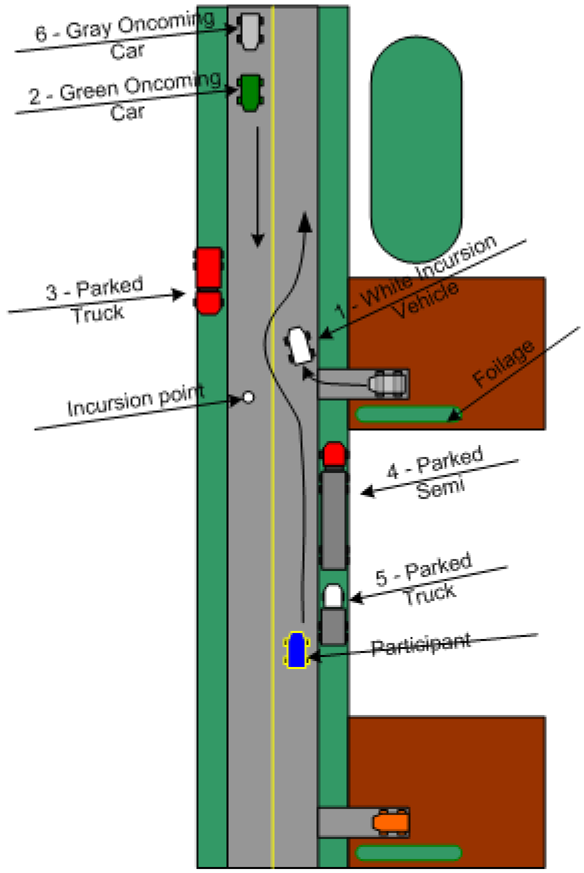

Figure 4. Scenario map for right incursion

2.3.2.3 Left Incursion

In this scenario, the participant is driving down a 2-lane road with oncoming traffic, and several semi-trucks are parked along the left side of the road. A vehicle that is hidden from view by one of the trucks pulls out at the last minute into the participant's lane. The participant must try to avoid the vehicle by applying the brakes and swerving either to the left or the right. In order to make the maneuver and avoid the vehicle, the participant must turn the wheel hard left or hard right. This event is illustrated in Figure 5.

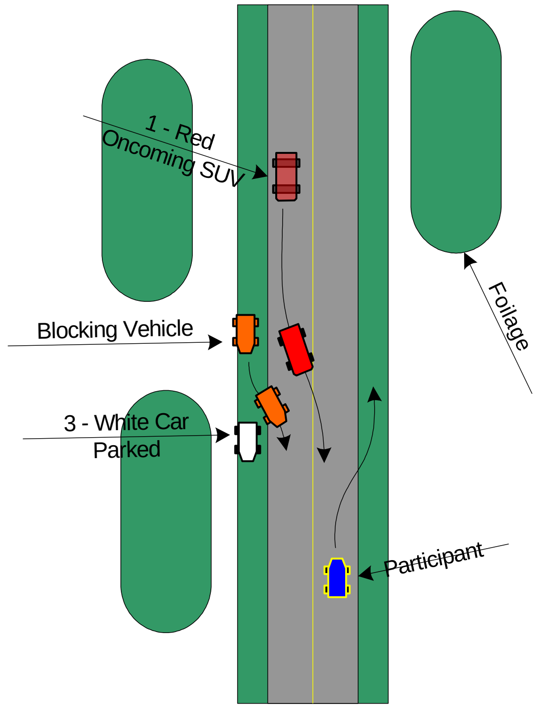

Figure 5. . Scenario map for left incursion

2.4 Driving Simulator

Data collection took place at the NADS research facility using the NADS quarter-cab miniSim research driving simulator. This miniSim has three 42-inch 720p plasma displays (see Figure 6). The miniSim includes three screens (each 3.0 feet wide by 1.7 feet tall) placed 4 feet away from the driver's eye point. This configuration produces a horizontal field of view of 132 degrees and a vertical field of view of 24 degrees. Visual icons could be displayed within the visual field, for example, on the A-pillars, in the rearview mirror, in the configurable instrument panel, as additional equipment on the dash, or in other appropriate locations relative to the driver's eye point. The audio system default included speakers mounted below the left and right displays. The driving performance data relating to lane position, speed, steering, throttle pedal, and brake pedal are all recorded at 60 Hz. This simulator is not equipped with any motion capabilities and does not provide haptic feedback.

Figure 6. Quarter-cab minSim

3 Results

The results are divided into two sections. First, driving performance under normal driving conditions will be considered. Data from this study is compared against data from a control group of 86 individuals also collected on the minSim as part of prior research. Second, emergency response performance will be considered.

3.1 Normal Driving

Three primary steering measures were considered:

- Standard deviation of lane position (SDLP) – a primary measure of impaired vehicle control.
- Steering frequency – a measure indicating the cutoff frequency at which half of the power is lost when conducting a power density analysis.
- Steering reversal rate – a measure of how frequently steering inputs greater than 6 degrees are being input.

There were no observed differences for SDLP, as can be observed in Table 1. There were, however, significant differences related to steering input as can be seen in Table 2 and Table 3. Drivers recovering from a DRF had lower cut-off steering frequencies indicative of slower- or smaller-magnitude steering inputs. They also had fewer reversals for the urban curves and gravel road segments.

For speed, average speed relative to the speed limit was assessed. As can be seen in Table 4, for most driving segments, drivers in the fracture group drove more slowly than the control drivers.

Table 1. Standard deviation of lane position (cm)

Segment	Fracture Group			Control Group			p-value
	Median	Min	Max	Median	Min	Max	
Left Turn	1.43	0.77	1.61	1.23	0.72	3.32	0.3325
Urban	0.79	0.42	1.00	0.73	0.44	1.73	0.8987
Urban Curves	0.92	0.62	1.16	0.95	0.51	1.65	0.6703
Turning off Ramp	1.73	0.97	2.12	1.54	0.46	2.49	0.4225
Dark Rural	1.13	0.77	1.70	1.23	0.64	2.15	0.7289
Gravel Transition	2.14	1.73	2.85	1.91	0.99	6.23	0.2440
Gravel	0.82	0.38	0.98	0.88	0.36	1.91	0.4165

Table 2. Steering frequency (Hz)

Segment	Fracture Group			Control Group			p-value
	Median	Min	Max	Median	Min	Max	
Left Turn	4.70	2.26	5.77	5.95	2.87	7.5	0.1239
Urban	1.23	0.82	1.70	1.63	1.00	2.49	0.0425
Urban Curves	1.08	0.88	1.32	1.70	1.14	2.78	0.0012
Turning off Ramp							
Dark Rural	1.60	1.38	1.67	1.90	1.44	2.58	0.0086
Gravel Transition	1.25	0.88	1.64	1.95	1.49	5.42	0.0012
Gravel	1.13	0.97	1.41	1.76	1.32	2.72	0.0010

Table 3. Steering reversal rate (1/min)

Segment	Fracture Group			Control Group			p-value
	Median	Min	Max	Median	Min	Max	
Left Turn	18.48	4.68	23.47	15.28	6.08	43.95	0.9610
Urban	2.13	0.00	6.97	3.75	0.00	33.39	0.3676
Urban Curves	2.12	0.95	2.52	4.89	0.37	26.38	0.0087
Turning off Ramp	13.98	7.38	39.64	15.34	2.20	41.92	0.9763
Dark Rural	5.87	2.70	7.58	8.19	1.23	22.23	0.1248
Gravel Transition	3.17	0.00	8.82	8.48	0.00	36.11	0.9880
Gravel	0.51	0.00	1.69	2.75	0.00	20.98	0.0071

Table 4. Average speed relative to speed limit (ft/s)

Segment	Fracture Group	Control Group	

	Median	Min	Max	Media n	Min	Max	p-value
Left Turn	-9.58	-12.15	-4.64	-4.80	-13.03	14.83	0.0514
Urban	-2.81	-4.21	-0.51	1.91	-3.49	22.10	0.0016
Urban Curves	-8.38	-11.56	-5.11	-2.50	-6.54	11.68	0.0013
Turning off Ramp	-15.74	-23.10	-11.54	-15.07	-28.25	-7.00	0.8199
Dark Rural	-4.57	-13.72	-1.97	-1.44	-11.53	8.56	0.0349
Gravel Transition	-9.36	-18.68	2.28	1.43	-20.22	13.63	0.0427
Gravel	-7.19	-14.66	0.88	7.33	-16.25	19.45	0.0080

3.2 Emergency Response

Three emergency response events were considered. Tables 5-7 illustrate the crash occurrence and the steering response. For the avoidance event, which was the week 2 event for the subjects, 3 of 4 crashed, and one driver did not even provide a steering response. For the drivers who crashed, maximum steering wheel angle was less than 42 degrees, whereas the driver who avoided crashing had a steering input greater than 50 degrees.

Table 5. Steering response by crash for avoidance event

		Crash		Total
		No	Yes	
Steering Response	Left	1	1	2
	None	0	1	1
	Right	0	1	1
Total		1	3	4

Table 6. Steering response by crash for left-incursion event

		Crash		Total
		No	Yes	
Steering Response	Left	1	0	1
	None	2	0	2
	Right	1	0	1

Total	4	0	4

Table 7. Steering response by crash for right-incursion event

		Crash		Total
		No	Yes	
Steering Response	Left	1	2	3
	None	0	0	0
	Right	0	0	0
Total		1	2	3

4 Discussion

Preliminary results suggest that patients 2 weeks after DRF volar plating are able to maintain lane position but with overall lower speed and fewer steering inputs, and with 75% (3 of 4) failing to avoid collision on a crash-avoidance task. With continued enrollment, a larger sample size will provide further insight into when DRF patients may safely return to driving.

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