Relationship of Sacral Fractures to Nerve Injury: Is the Denis Classification Still Accurate?

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Background/Purpose: Sacral fractures were largely undiagnosed until 1988, when Denis et al published a groundbreaking paper that classified sacral fractures in accordance with location and symptoms by analyzing radiographs and a limited number of computed tomography (CT) scans from a study population of 236 patients. The Denis classification identifies risk of neurologic injury correlated with sacral fractures by using a progressive severity scale divided into 3 anatomical zones: Zone I (sacral ala; 61-C1.3, c, a1), Zone II (transforaminal; 61-C1.3, c, a2), and Zone III (central sacral canal; 61-C1.3, c, a3). However, recent studies have shown that radiographs have limited power in assessing fractures. Alternatively, modern advances in imaging increase diagnostic sensitivity for determining the classification of these fractures and their corresponding neurologic injuries. Thus, it is hypothesized that the identified neurologic injury risks associated with specific sacral fractures are lower than reported in the original Denis et al paper.

Methods: A retrospective study of 683 consecutive patients with sacral fractures in a series of 1507 patients with pelvic fractures was conducted by analyzing fine-cut CT scans using the Denis classification. Chart review was used to evaluate for associated nerve injuries. Patients were stratified based on the diagnosis of acute nerve injury at presentation. Fisher's exact test was used to determine statistical significance between the frequency of nerve injuries associated with each zone in our study population and in the population in the original Denis paper.

Results: Overall neurologic injury associated with sacral fracture was low at 3.5% as compared with 21.6% in the original Denis paper. Of the sacral fractures evaluated, 66% were Zone I fractures, 25% were Zone II fractures, and 9% were Zone III fractures. These are approximately equivalent to the original Denis paper. Within these subpopulations, 1.9% of nerve injuries were associated with Zone I fractures, 5.8% were associated with Zone II fractures, and 8.6% were associated with Zone III fractures. The frequency of neurologic injuries associated with each specific fracture type was significantly lower in our patient population than published in the original paper ($P = 0.046$). Patients with nerve injuries were significantly correlated with spinopelvic dissociation ($P = 0.048$; 61-A3.3) and comminuted fracture patterns ($P = 0.001$) compared to those without nerve injury. In addition, Zone III injuries were significantly more frequent in patients with associated nerve injury ($P = 0.006$). Patients with nerve injury more often underwent surgical intervention ($P = 0.037$).

Conclusion: The significantly lower frequency of neurologic injuries associated with specific sacral fractures in our study population confirms our hypothesis that nerve injuries associated with each Denis classification are much less common than reported in the original paper. These findings indicate that, in comparison to radiographs, CT scans allow for more accurate diagnosis of sacral fractures and their associated neurologic injuries due to an increased level of detail that helps to limit misdiagnosis. Hence, it may be recommended

See pages 49 - 106 for financial disclosure information.

that all patients with pelvic and/or sacral injuries receive CT scans, preferably with 0.6 mm cut. In addition, patients with nerve injury more often presented with Zone III fracture or spinopelvic dissociation. As such, we encourage physicians treating sacral fractures to have a very high index of suspicion for Zone III fracture or spinopelvic dissociation whenever a nerve injury is present. Further research is warranted to evaluate short- and long-term nerve function in patients who present with these complex fracture patterns, due to persistence of neurologic deficit.

Table 1 – Patient demographics, injury characteristics, and post-operative outcomes based upon the presence of nerve injury

	Associated Nerve Injury (n=24)	No Nerve Injury (n=659)	p-value
Age	46.6±19.1	43.4±19.3	0.425
% Female	45.8%	45.2%	0.953
Body mass index	27.9±9.9	27.6±6.9	0.843
Bilateral Fracture	20.8%	9.7%	0.076
Spinopelvic dissociation	16.7%	6.4%	**0.048**
Displacement - Non-displaced - Minimally displaced - Displaced - Comminuted	 37.5% 8.3% 8.3% 45.8%	 62.1% 18.5% 3.2% 16.2%	**0.001**
Mechanism of Injury* - Fall - High energy - Other	 12.5% 75.0% 12.5%	 24.0% 70.7% 5.3%	0.173
Zone of injury** - Zone 1 - Zone 2 - Zone 3	 37.5% 41.7% 20.8%	 67.4% 24.6% 8.0%	**0.006**
% Surgery	20.8%	8.5%	**0.037**
Post-operative management			
Weight bearing status - Non-weight bearing - As tolerated	 62.5% 37.5%	 51.0% 49.0%	0.268
DVT Prophylaxis	58.3%	44.9%	0.195
Pain medication - Narcotics - Acetaminophen	 100% 0.0%	 96.5% 3.5%	0.352
Physical therapy	79.2%	62.5%	0.097
Abnormal nerve function at follow up***	29.2%	2.4%	**<0.001**

* High energy include: motor vehicle accident, pedestrian vs vehicle, or motorcycle accident. Other include: Tractor accident, bicycle accident, or ATV
** Based on Denis classification
***3-6 weeks