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Nerve Injury Associated with Anesthesia

A Closed Claims Analysis

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Background: **Nerve injury associated with anesthesia is a significant source of morbidity for patients and liability for anesthesiologists. To identify recurrent and emerging patterns of injury we analyzed the current American Society of Anesthesiologists (ASA) Closed Claims Project Database and performed an in-depth analysis of claims for nerve injury that were entered into the database since the authors' initial report of the subject.**

Methods: **The ASA Closed Claims Database is a standardized collection of case summaries derived from the closed claims files of professional liability insurance companies. Claims for nerve injury that were not included in the authors' 1990 report were reviewed in-depth.**

Results: **Six hundred seventy (16% of 4,183) claims were for anesthesia-related nerve injury. The most frequent sites of injury were the ulnar nerve (28%), brachial plexus (20%), lumbosacral nerve root (16%), and spinal cord (13%). Ulnar nerve (85%) injuries were more likely to have occurred in association with general anesthesia, whereas spinal cord (58%) and lumbosacral nerve root (92%) injuries were more likely to occur with regional techniques. Ulnar nerve injury occurred predominately in men (75%) and was also more apt to have a delayed onset of symptoms (62%) than other nerve injuries. Spinal cord injuries were the leading cause of claims for nerve injury that occurred in the 1990s.**

Conclusion: **New strategies for prevention of nerve damage cannot be recommended at this time because the mechanism for most injuries, particularly those of the ulnar nerve, is not apparent. (Key words: Anesthesia complications; liability payment; medicolegal; standard of care.)**

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NERVE injuries are a well-recognized complication of anesthesia.[1–4] We previously reported[1] an analysis of claims for nerve injury from the American Society of Anesthesiologists (ASA) Closed Claims Project in 1990. Of 1,541 claims reviewed at that time, 227 (15%) were for anesthesia-related nerve injury. The most recent claim in that set of nerve injuries occurred in 1985. The most frequent nerve injuries were to the ulnar nerve (34%), brachial plexus (23%), and lumbosacral nerve root (16%). Because claims entered into the database after this early report contain much more in-depth information, we analyzed the nerve injury claims entered into the database since the 1990 report to see whether previously unrecognized patterns of nerve injury could be identified that might suggest strategies for their prevention. We also analyzed the entire database of 4,183 claims to provide an updated description of claims for nerve injury and to assess liability trends as related to the date the nerve injury occurred.

Methods

The ASA Closed Claims Project is a structured evaluation of adverse anesthetic outcomes obtained from the closed claims files of 35 US professional liability insurance companies. Claims for dental damage are not included in this project. A detailed description of the data collection process has been reported.[5] In brief, a closed claim file for an adverse anesthetic outcome usually consists of relevant hospital and medical records, narrative statements from involved healthcare personnel, expert and peer reviews, deposition summaries, outcome reports, and the cost of settlement or jury award. Each claim was reviewed by a practicing anesthesiologist according to a standardized set of instructions. The reviewers used a standardized form to record information regarding patient characteristics, surgical procedures, sequence and location of events, critical incidents, clinical manifestations of injury, appropriateness of anesthesia care, and outcome. Reviewers also wrote a narrative description of each case that summarized the sequence of events and provided additional details. The reliability of reviewer assessments of the appropriateness of anesthesia care has been found to be acceptable.[6]

Data for the overview of nerve injury claims were drawn from the entire Closed Claims Project database of 4,183 claims, including the 1,541 claims analyzed in our previous report.[1] For the current analysis, the term *nerve damage* was used to describe injuries in which there were clinical, anatomic, or laboratory findings consistent with damage to discrete elements of the spinal cord or peripheral nervous system. Typical findings included sensory or motor changes following recognized neuroanatomic distributions, electrophysiologic data from nerve conduction studies or electromyography, and surgical descriptions of adhesion or entrapment of nerve structures. Known specific pain syndromes (*e.g.*, low back pain, muscle aches, jaw soreness) that could not be linked to specific neuroanatomic lesions were not included in the category of nerve damage. Brain damage and vocal cord palsies were also excluded. The claims include perioperative nerve injury and nerve injury related to acute and chronic pain management.

To define the changes in liability patterns over time, we evaluated the date of occurrence of the adverse outcome for all nerve injury claims in the database, including those in our previous report.[1] We evaluated liability trends in claims for nerve injury compared to all other claims in the database. We also analyzed patterns of injury and liability within the most-common nerve injury groups. Claims for injury to multiple discrete nerves were classified separately and excluded from the individual nerve injury groups.

The database for the current in-depth analysis consists of 2,651 claims reviewed since 1990 for adverse outcomes that occurred between 1975 and 1995. Eighty-six percent of these adverse outcomes occurred between 1981 and 1992. The mechanism of injury is defined as the physiologic process or abnormality that played the primary role in producing the injury, such as direct trauma by surgical or anesthesia instruments or explicitly observed hyperextension or compressions of the extremity, as reported by the closed claims reviewers based on all available information in the claim file. For each of the most common nerve injuries, we reviewed the standardized closed claim data collection form and narrative description for factors associated with administration of anesthesia (*e.g.*, paresthesia during injection of local anesthesia, onset of symptoms, patient position, and padding) or patient physiology (*e.g.*, preoperative history of symptoms, pathology associated with high risk for neurologic problems, injuries to other nerves). These associated factors differed for the different nerve injuries, being drawn from previously established theories about their causation.

Differences in proportions (sex, appropriateness of care, incidence of payment, primary anesthetic technique) were tested for statistical significance using the Z test,[7] as were trends over time. Payment amounts were compared for differences in their distribution using the Kolmogorov-Smirnov test.[8] Age differences were tested by Mann–Whitney U Test.[8] The association between appropriateness of care and the use of elbow padding in ulnar nerve injury claims was tested by Fisher exact test with Monte Carlo significance calculated from 10,000 sampled tables.[9] Two-tailed tests were used to determine statistical significance at $P \leq 0.05$.

Results

Overview of 670 Nerve Injuries in Database of 4,183 Claims

The major injuries in the 4,183 claims in the Closed Claims Project database were death (32%), nerve damage (16%), and brain damage (12%). The distribution of the 670 nerve injury claims is shown in table 1. Ulnar neuropathies were most frequent, followed by injuries to the brachial plexus, lumbosacral nerve root, and spinal cord. Much less commonly affected were sciatic, median, radial, and femoral nerves (table 1). A wide variety of injuries, each with a frequency of 1% or less, accounted for the remaining 8% of claims for nerve injury. The injuries were bilateral in 14% of ulnar injuries and in 12% of brachial plexus injuries.

Nerve damage claims were filed in equal proportions by males and females (table 2). This differs from non-nerve damage claims that were filed predominately by females (61%, $P \leq 0.01$). Men predominated in ulnar nerve injury claims (75%, $P \leq 0.01$). The median ages of

Table 1. Distribution of Claims for Nerve Injury

Nerve	Number of Claims in Current Database (N = 4,183)	% of 670	Number of Claims since 1990 Report	% of 445
Ulnar	190	28	113	25
Brachial plexus	137	20	83	19
Lumbosacral nerve root	105	16	67	15
Spinal cord	84	13	73	16
Sciatic*	34	5	23	5
Median	28	4	19	4
Radial	18	3	13	3
Femoral	15	2	9	2
Other single nerves†	43	6	35	8
Multiple nerves†	16	2	10	2
Total	670	100	445	100

* Includes peroneal (or fibular) never injury.

† Includes accessory, axillary, cervical nerve root, cranial nerves, ilioinguinal, musculocutaneous, obturator, perineal, phrenic, pudendal, suprascapular, supraspinatus, trigeminal, reflex sympathetic dystrophy.

patients with ulnar nerve (50 yr) and spinal cord injuries (54 yr) were significantly higher ($P < 0.001$) than the median age of non–nerve damage claimants (39 yr).

General anesthesia was less frequently and regional anesthesia was more frequently associated with nerve damage claims as compared to non–nerve damage claims. Ulnar nerve injuries were associated predominately with general anesthesia (85%), whereas injuries to the spinal cord and lumbosacral nerve root were associated predominately with regional anesthesia (58% and 92%, respectively; fig. 1).

Anesthesia care was judged as appropriate in 66% of all nerve injury claims as compared with only 42% of claims not involving nerve damage ($P \leq 0.01$, table 3). Compared with non–nerve damage claims, reviewers judged care as having met standards significantly more often in all categories of nerve damage except spinal cord injury. The frequency of payment (45%) and median payment ($35,600) were lower for nerve damage claims than for claims not involving nerve damage (57%, $P \leq 0.01$ and $125,000, $P \leq 0.001$, respectively). The likelihood of payment was lower in ulnar, brachial plexus, and lumbosacral nerve root injuries as compared with non–nerve damage claims. Among the subset of claims with appropriate care, the payment rate for ulnar nerve injury claims (47%) differed from non–nerve injury claims (35%, $P \leq 0.01$). Among the individual nerves involved, only spinal cord injuries had a higher median payment ($258,500) than non–nerve damage claims ($P = 0.010$).

Analysis of the entire 670 nerve injuries in the database of 4,183 claims showed significant trends in liability patterns for nerve injury over time. The date of occurrence of injury of ulnar nerve damage claims as a percent of total nerve injuries decreased from 37% in 1980–1984 to 17% of claims in which the injury occurred in the 1990s ($P \leq 0.05$, fig. 2). Conversely, in the 1980–1984 time period, the occurrence of spinal cord injury represented only 8% of the total nerve injury claims, but in the 1990s this had increased to 27% ($P \leq 0.05$). Data accu-

Table 2. Distribution of Most Frequent Injuries by Gender and Age

	% Male	% Female	Median Age (yr)	Age Range (yr)	% < 16 yr
Non–nerve damage (n = 3,513)	38	61	39	0–94	11
All nerve damage (n = 670)	50*	49*	44*	1–86	1*
Ulnar (n = 190)	75*	23*	50*	20–82	0*
Brachial plexus (n = 137)	40	58	41†	1–80	1*
Lumbosacral root (n = 105)	29†	71†	37	20–83	0*
Spinal cord (n = 84)	52†	48†	54*	2–86	5†
All other nerves (n = 154)	42	58	40	5–81	2*

* $P \leq 0.01$ *versus* non–nerve damage claims.

† $P \leq 0.05$ *versus* non–nerve damage claims.

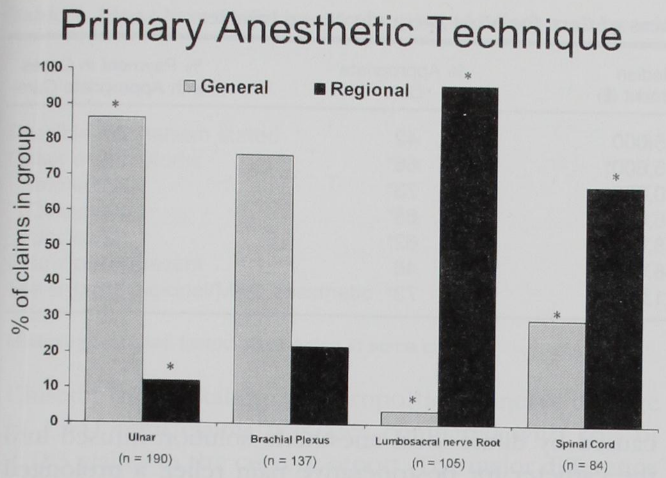

Fig. 1. Incidence of general and regional anesthesia in each category of nerve damage. *$P \leq 0.05$ compared to non–nerve damage.

mulated to date in the 1990s indicate spinal cord injury as the leading cause of claims for nerve damage.

In-depth Analysis of 445 Nerve Injury Claims: Mechanism of Nerve Injury and Associated Factors

Among the 2,651 claims added to the database since our previous report,[1] there were 445 claims for nerve injury (table 1). The distribution of claims for the various nerve injuries in this subset used for in-depth analysis reflected the distribution in the entire set of 670 nerve injuries in 4,183 claims.

With the exception of spinal cord injury, the actual mechanism of injury was not apparent in the file of most claims for nerve injury. However, there were a number of factors associated with many of the claims that suggested a possible mechanism of injury. In particular, claims for ulnar nerve injury exhibited recurrent associated factors, which raised questions about when the injury occurred or which might have been expected to prevent the injury.

The mechanism of injury was explicitly stated in the claim file in only 10 (9%) of 113 ulnar nerve injuries (table 4). Four were attributed to preoperative trauma. The remaining injuries were attributed to intraoperative trauma (n = 1), the surgical procedure (n = 1), the use of crutches (n = 1), and the performance of an axillary block (n = 3). Paresthesias were not present during the performance of the block in any of these cases. In another four claims, the ulnar nerve injury was present before surgery, although the cause of the injury was not stated. The onset of symptoms of injury was noted immediately postoperatively in 21% of ulnar nerve claims and was delayed from 1–28 days postoperatively (median 3 days) in 62%. Addition of padding to the elbows was explicitly stated as being present in 27% of all ulnar nerve injuries. In addition, there were eight claims in which ulnar neuropathy occurred in patients who were sedated and underwent spinal, epidural, or local anesthesia for lower-body surgical procedures. None of these factors had a significant association with the incidence or the amount of payment or reviewers' judgments about the appropriateness of care.

Eight of 83 (10%) brachial plexus injuries were clearly related to patient position, such as the use of shoulder braces and the head-down position (four claims), malposition of the arms (three claims), and sustained neck extension (one claim, table 5). As expected, care was judged as less than appropriate in all of these claims. Of the 13 brachial plexus injuries associated with regional block, paresthesias were specifically noted in 4 axillary blocks. In two of these blocks, paresthesias occurred during injection of the local anesthetic. There were two claims for brachial plexus injury caused by sternal retraction during cardiac surgery. There were 11 claims for long thoracic nerve injury, most of which occurred in healthy women (9 claims) in their 20s and 30s, undergoing cesarean section (3 claims) or gynecologic (4 claims) procedures. Of these 11 claims, 8 patients underwent general anesthesia, whereas 3 underwent lumbar epidurals. The only claim with a suggested mechanism of the long thoracic nerve injury was a 28-yr-old man who had a shoulder arthrodesis and was thought to have a "rucksack" injury.

Most spinal cord injuries in the database resulted in paraplegia (45 claims) or quadriplegia (15 claims). The mechanism of injury was noted in 35 (48%) claims (table 6). The most common mechanisms of spinal cord injury were epidural hematoma, chemical injury, anterior spinal artery syndrome, and meningitis. A regional anesthetic was administered in 50 (68%) spinal cord injuries. These included 35 lumbar epidurals, 9 subarachnoid blocks, and 4 thoracic epidural blocks. Major factors associated with spinal cord injury were blocks for chronic pain management (14 claims) and systemic anticoagulation in the presence of neuraxial block (13 claims). The blocks for chronic pain management included eight lumbar epidurals for steroid injection.

Among the 23 spinal cord injury claims that were not associated with regional anesthesia, surgery was performed on the cervical or lumbar spine in 11. In two others, cervical cord injury occurred when the patient fell off the operating room table. In the 13 claims for

Table 3. Incidence of Payment, Median Payment, and Appropriateness of Care for Most Frequent Nerve Injuries

	% Payment	Median Payment ($)	% Appropriate Care	% Payment in Cases with Appropriate Care
Non–nerve damage (n = 3,513)	57	125,000	42	35
All nerve damage (n = 670)	45*	35,600*	66*	38
Ulnar (n = 190)	48†	20,000*	73*	47*
Brachial plexus (n = 137)	41*	36,600*	65*	34
Lumbosacral root (n = 105)	44†	58,014	62*	32
Spinal cord (n = 84)	62	258,500*	46	46
All other nerves (n = 154)	36*	21,250*	73*	30

* $P \leq 0.01$ *versus* non–nerve damage claims.

† $P \leq 0.05$ *versus* non–nerve damage claims.

spinal cord injury in patients who were anticoagulated with intravenous heparin, epidural hematoma occurred after lumbar epidural (11 claims) or subarachnoid block (2 claims) and resulted in paraplegia. All patients were undergoing vascular surgical or diagnostic procedures. Epidural catheters were used in eight of these patients intraoperatively, and in seven the catheter was left in place postoperatively. In three claims the patient was administered heparin for anticoagulation preoperatively. All 13 patients were administered intraoperative heparin, and in 5 heparin administration continued into the postoperative period. In 10 claim files it was explicitly stated that delayed diagnosis of the epidural hematoma was a major factor in the resultant injury. The factors involved in the delayed diagnosis of the epidural hematoma were the interpretation by the caregivers that persistent numbness or lower extremity weakness was caused by dilute local anesthetic solution infused into the catheter for postoperative pain relief, a prolonged effect of the local anesthetic used for surgery or by diabetic neuropathy. The care was judged as appropriate in only 1 of these 13 claims, and the median payment was very high ($447,381).

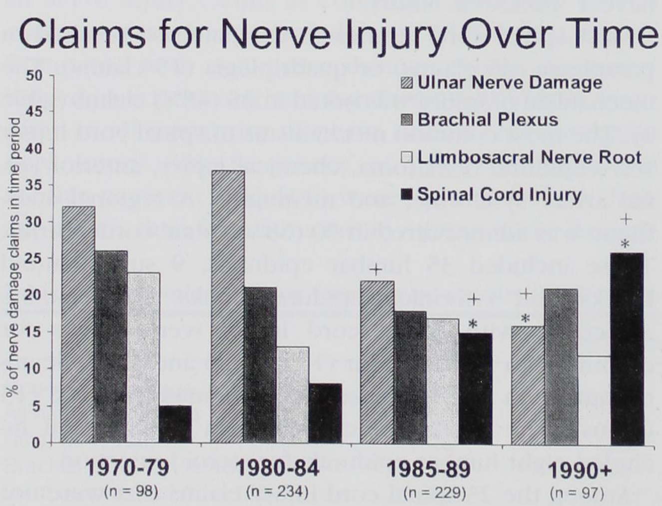

Fig. 2. Proportion of claims in each major category of nerve damage by time of occurrence of the injury. The data are derived from 670 claims for nerve injury in the entire Closed Claims Project Database of 4,183 claims. *$P \leq 0.05$ compared to 1970–1979. †$P \leq 0.05$ compared to 1980–1984.

Ninety-three percent of 67 lumbosacral nerve root injuries were associated with the administration of spinal (37 claims) or epidural (25 claims) anesthesia. The major associated factors noted were paresthesia during needle insertion (18 spinal/6 epidural) or injection of drug (seven epidural spinal/one epidural), or multiple attempts to perform a block (10 spinal/4 epidural). In one claim, multiple attempts at lumbar epidural were made with the patient under general anesthesia. Only one claim noted the possibility of 5% lidocaine toxicity in a spinal anesthetic. Of the 23 sciatic injuries, which included 11 peroneal nerve injuries, 10 were associated with the lithotomy and 2 with the frog-leg operative position. There were 13 radial nerve injuries, 3 of which were associated with axillary blocks (1 with paresthesia, 1 performed during general anesthesia). Of the 19 median nerve injuries, 5 were associated with axillary block (2 with paresthesias). There were four claims in each of the radial and median nerve injury groups related to alleged needle trauma from starting (six claims) or from infiltration of (two claims) an intravenous infusion.

Discussion

Perioperative nerve injury continues to be a significant source of injury for the anesthetized patient. Although the proportion of claims for death have decreased significantly from our 1990 report[1] (37 to 32%, $P \leq 0.01$), the proportion of claims for nerve injury has remained essentially constant. In our 1990 report[1] from the ASA

Table 4. Ulnar Nerve Injuries: Mechanism of Injury and Associated Factors

	n	% of 113	Incidence of Payment (%)	Median Payment ($)	% Appropriate Care
Possible mechanism stated	10	9	30	12,832	80
Onset of symptoms					
Immediate	24	21	42	37,500	71
Delayed	70	62	46	33,375	84
Unclear	19	17	42	47,500	53
Elbow pads present	30	27	50	18,000	87
Lower body regional/MAC anesthetic	8	7	50	9,250	88

Multiple associated factors were noted in some claims.

Closed Claims database, the proportion of nerve damage in 1,541 total claims was 15% compared with 16% of 4,183 claims in the current report. The major difference in the pattern of nerve injury between the 1990 report and the current analysis is a relative decrease in the percentage of ulnar nerve injury as a proportion of the total nerve injury claims and the increase in the proportion of claims for spinal cord injury. In the 1990s in the ASA Closed Claims database, spinal cord injury has surpassed ulnar nerve injury as the leading cause of claims for nerve injury (fig. 2).

As in the previous report,[1] it was notable how rarely a definite mechanism of injury was explicitly stated in the file despite extensive medical legal investigation. The exception to this was spinal cord injury in which the mechanism was noted in 48% of claims. Some of the mechanisms of injury described in the literature[10] were observed in the claim files of cases involving brachial plexus injuries. Although the mechanism of ulnar nerve injuries was apparent in 10 (9%) of the ulnar nerve claims (table 4), in only 3 claims could an anesthesia-related mechanism (axillary block) be inferred. Anesthesia-related perioperative ulnar nerve injury is often ascribed to malposition of the elbow, with the ulnar nerve being compressed on a hard surface during surgery, or stretched in some fashion.[10] It is notable that in 30 of 113 claims (27%), extra padding over the elbows was explicitly noted in the file. This casts some doubt on the theory that nerve compression is a frequent mechanism of intraoperative anesthesia-related ulnar nerve injury.

Table 5. Factors Associated with Brachial Plexus Injuries

	n	% of 83
Block*	13	16
Patient position	8	10
Surgical trauma	4	5
Preexisting injury	2	2

* Includes eight axillary, four interscalene, and one supraclavacular.

Further evidence against malposition or compression as a common mechanism of ulnar nerve injury is the finding that eight claims for perioperative ulnar nerve injury were from patients who underwent spinal, epidural, or local anesthesia for lower body surgical procedures. All were awake or sedated during the surgical procedure with signs and symptoms of ulnar neuropathy usually becoming apparent 1-4 days after surgery. Similarly, Warner *et al.*[11] reported ulnar neuropathy occurring in patients who underwent sedation (71 patients) only or regional anesthesia (26 patients). It would seem reasonable that an awake or lightly sedated patient would be aware of compression or stretch of the ulnar nerve extreme enough to cause injury.

The male predominance of perioperative ulnar nerve injury (nearly 3 to 1 in this report) has been observed previously.[1,4,11] This is in marked contrast to the non-nerve injury claims in which more than 60% were filed by females and suggests an anatomic predisposition in men. The delayed onset of symptoms is also a notable feature of ulnar neuropathy. In the current report, the symptoms of ulnar neuropathy were explicitly noted as being present in the immediate postoperative period in

Table 6. Mechanism of Spinal Cord Injury

Mechanism of Injury	n (% of 73)	Pain Block [no. (%)]
Epidural hematoma	16 (22)	2 (3)
Chemical injury*	5 (7)	3 (4)
Anterior spinal artery syndrome	4 (5)	0 (0)
Meningitis	4 (5)	3 (4)
Trauma from fall	3 (4)	0 (0)
Epidural abscess	2 (3)	1 (1)
Intradural or intraspinal hematoma	1 (1)	0 (0)
Total	35 (48)†	

* Anesthesia or neurolytic agent injected into spinal cord and intravascular injection.

† Proportions do not sum to total due to rounding error.

only 21% of these claims. In 62%, the onset of symptoms was explicitly noted as delayed by 1-28 days, with a median delay of 3 days (table 4). Warner *et al.*[11] also noted a delay in onset of symptoms of ulnar neuropathy in 57% of patients undergoing general anesthesia. This delayed onset of symptoms suggests that the damage might not occur intraoperatively, but at a later time in the hospital course or even after discharge.

Clearly, ulnar neuropathy occurs despite conventional methods of positioning and padding. Certain patient populations may be more susceptible to this injury. For example, Alvine[12] performed bilateral nerve conduction studies in 17 patients, 15 of whom were men, in whom perioperative ulnar neuropathy developed and found abnormal nerve conduction on the side opposite the symptomatic nerve in 12 of 14 patients with unilateral symptoms. This suggests that there may have been a subclinical ulnar neuropathy that may have become symptomatic as a result of the manipulations performed in the perioperative period. Warner *et al.*[11] also noted bilateral ulnar neuropathy in 9% in a series of 414 patients with ulnar neuropathy. Unlike Warner *et al.*,[11] we did not find any relation between obesity and the occurrence of ulnar neuropathy. This could well be a result of the fact that information about either the presence or the absence of obesity was not recorded in all claims. Clearly, the occurrence of ulnar neuropathy is related to age because the median age of patients with ulnar neuropathy was 50 yr and the youngest was age 20 yr (table 2). The total absence of ulnar neuropathy in the pediatric age group is notable.

Although occurring less frequently than ulnar neuropathy, the mechanism of long thoracic nerve injury is equally puzzling. This injury occurred predominately in women (9 of 11 claims) in their 20s and 30s. The occurrence of the injury in three patients who were awake during lumbar epidural anesthesia is also a puzzle. Martin[13] reported six cases of long thoracic nerve injury occurring in patients undergoing anesthesia (five general, one epidural), four of which were women. The author commented on the lack of apparent mechanism and proposed a coincidental infectious neuropathy as the possible cause of the long thoracic nerve injury.[13]

The anesthesia care was significantly more often judged as appropriate in ulnar nerve (73%), brachial plexus (65%), and lumbosacral nerve root (62%) injury claims, as compared to non-nerve damage claims (42%, table 3). Despite appropriate care, payment was made for the nerve injury in 38% of claims with appropriate care. Payment was made in 47% of the ulnar nerve injury claims in which care was appropriate. Payment was even made in 50% of the ulnar nerve damage claims in which the patient was awake or sedated during regional anesthesia and the surgery was performed on the lower body. Although the rate of payment in claims with appropriate care does not differ significantly between nerve injury and non-nerve injury claims (table 3), clearly, factors other than standard of care influence whether payment was made. The lack of apparent mechanism poses a problem for the defense of these nerve injury claims because the presumption is often made by the patient, the patient's attorney, and by consulting specialists that something must have been performed incorrectly by the anesthesiologist during the perioperative period.

Spinal cord injuries were the exception to the lack of apparent mechanism seen in most nerve injury claims. The payment rate and proportion of claims in which care was judged as appropriate was about the same as for non-nerve damage claims (table 3). The higher payments for spinal cord injuries compared to non-nerve damage claims may be related to the severity of the injuries (paraplegia and quadriplegia). The best examples of substandard care leading to injury are the 13 claims in which epidural hematoma occurred in anticoagulated patients who underwent neuraxial blocks. In most of the cases, postoperative care was judged as inappropriate, in that the signs and symptoms of epidural hematoma were not readily appreciated by the healthcare team. As a result, care was judged as substandard by the reviewers in 12 of 13 claims, payment was made in 9 claims, and the median payment was very high ($447,381). The lesson to be learned from this collection of claims is that if neuraxial block is performed in the presence of systemic heparinization, the patient should be monitored carefully and that any unexpected motor or sensory changes should be strongly considered as potential evidence for an epidural hematoma. Because the most recent of these claims in the database at the time of this review are from 1992, we could not expect to have any claims for epidural hematoma occurring in the presence of low-molecular-weight heparin, because the drug was not approved by the Food and Drug Administration for general use until May 1993.[14]

The significant increase in spinal cord injuries over time (fig. 2) seems to be related to injuries from neuraxial blocks in anticoagulated patients and blocks for chronic pain management. In our 1990 report, there was only one spinal cord injury associated with chronic pain management and no injuries associated with anticoagulated patients. The most recent date of any nerve injury in our previous report was 1985, whereas the spinal cord injuries in the in-depth analysis in this report occurred from 1983-1992. Because of our lack of denominator data, it is not clear whether the appearance of these injuries is a result of more blocks being performed under these circumstances, a more litigious patient population, or to other unknown factors.

Limitations of closed claims analysis include lack of data regarding the total population at risk for injury and nonrandom, retrospective data collection.[5] The sample of claims in the Closed Claims Project database is derived from liability insurers who consented to access to their confidential files. The panel of liability insurers sharing closed claims data insures approximately half of the practicing anesthesiologists in the United States. However, we do not know how many anesthetics were administered by these providers, and we lack data regarding specialization (*e.g.,* pain management) *versus* general anesthesia practice. To preserve the validity of longitudinal analysis of liability trends over time, data from new insurers added to the Closed Claims Project panel include all claims closed since inception of the company.

In conclusion, although ulnar neuropathy remains the most common anesthesia-related nerve injury, spinal cord injuries have become the most prominent complaint in claims for nerve injury occurring in the 1990s. With the exception of spinal cord injuries, the mechanism of injury was not readily apparent in the majority of claims for nerve injury.

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