

# Injuries and Liability Related to Central Vascular Catheters

## A Closed Claims Analysis

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**Background:** To assess changing patterns of injury and liability associated with central venous or pulmonary artery catheters, the authors analyzed closed malpractice claims for central catheter injuries in the American Society of Anesthesiologists Closed Claims database.

**Methods:** All claims for which a central catheter (*i.e.*, central venous or pulmonary artery catheter) was the primary damaging event for the injury were compared with the rest of the claims in the database. Central catheter complications were defined as being related to vascular access or catheter use or maintenance. Statistical analysis was performed using the chi-square test, Fisher exact test, or Z test (proportions) and the Kolmogorov-Smirnov test (payments).

**Results:** The database included 110 claims for injuries related to central catheters (1.7% of 6,449 claims). Claims for central catheter injuries had a higher severity of injury, with an increased proportion of death (47%) compared with other claims in the database (29%,  $P < 0.01$ ). The most common complications were wire/catheter embolus ( $n = 20$ ), cardiac tamponade ( $n = 16$ ), carotid artery puncture/cannulation ( $n = 16$ ), hemothorax ( $n = 15$ ), and pneumothorax ( $n = 14$ ). Cardiac tamponade, hemothorax, and pulmonary artery rupture had a higher proportion of death ( $P < 0.05$ ) compared with the rest of the central catheter injuries. The proportion of claims for vascular access injury increased (47% to 84%) and use/maintenance injury decreased (53% to 16%) in 1994–1999 compared with 1978–1983 ( $P < 0.05$ ).

**Conclusions:** Claims related to central catheters had a high severity of patient injury. The most common complications causing injury were wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, hemothorax, and pneumothorax.

CENTRAL vein catheterization, with insertion of a central venous or pulmonary artery catheter, is used extensively for perioperative hemodynamic monitoring. Re-

cently, the hazards of central catheterization<sup>1-3</sup> and its questionable value in improving survival<sup>4</sup> have been emphasized. Patient injuries from mechanical, infectious, and thrombotic complications are estimated to occur in more than 15% of patients in which central venous catheters are used.<sup>1-3</sup> In the 1990s, ultrasound guidance of central vein catheterization has been advocated as a means to reduce mechanical complications and placement failures compared with the landmark technique.<sup>5-7</sup>

The purpose of this closed claims review was to identify and describe changing patterns of injury and liability for anesthesiologists related to central venous or pulmonary artery catheterization. We analyzed closed malpractice claims related to central catheters using the American Society of Anesthesiologists (ASA) Closed Claims Project database, which contains claims against anesthesiologists since 1970. Although closed claims analysis only provides an indirect assessment of the risks of central catheters (because of the lack of denominator data), it does provide a snapshot of anesthesia liability.<sup>8-9</sup> The liability and clinical features associated with specific central catheter injuries were compared over time, during which practice patterns may have changed.

## Materials and Methods

The ASA Closed Claims Project is a structured evaluation of adverse anesthetic outcomes obtained from the closed claim files of 35 U.S. professional liability insurance companies. Claims for dental damage are not included in the database. The current study was based on a total of 6,449 claims for adverse outcomes that occurred between 1970 and 2000. These constitute all claims collected through December 2002. Sixty-four percent of the injuries leading to claims occurred between 1985 and 1999.

The data collection process has been previously described in detail.<sup>8,9</sup> Briefly, a closed claim file was reviewed by a practicing anesthesiologist and typically consisted of relevant hospital and medical records; narrative statements from involved healthcare personnel; expert and peer reviews; summaries of depositions from plaintiffs, defendants, and expert witnesses; outcome reports; and the cost of settlement or jury award. The reviewer used standardized instructions to fill out a standardized form that records information about patient

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characteristics, surgical procedures, sequence and location of events, critical incidents, clinical manifestations of injury, standard of care, and outcome.<sup>8</sup>

The physical or psychological injury for which the patient was seeking compensation was recorded in each claim. In some claims, there was no apparent injury. Some claims had multiple injuries. Each claim was assigned a severity of injury score that was designated by the on-site reviewer using the insurance industry's 10-point scale. This ordinal scale rates severity of injury from 0 (no injury) to 9 (death).<sup>8</sup> Values of 1 represent temporary emotional injury; 2–4 reflect temporary physical injuries; 5 reflects permanent, nondisabling emotional and physical injuries; and 6–8 reflect permanent and disabling emotional and physical injuries. For purposes of analysis, injuries were grouped into three categories: temporary-nondisabling (score = 0–5), disabling-permanent (score = 6–8), and death (score = 9). Appropriateness of anesthesia care was rated as standard (appropriate), substandard, or impossible to judge based on reasonable or prudent practice at the time of the event. The reliability of reviewer judgments previously has been found to be acceptable.<sup>10</sup>

The current study analyzed all claims for injuries for which a central catheter (*i.e.*, central venous or pulmonary artery catheter) was the primary damaging event. The primary damaging event is the primary mechanism causing the injury as classified by the on-site reviewer and reviewed by the Closed Claims Committee. The specific type of complication (*e.g.*, wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, pneumothorax, hemothorax, pulmonary artery rupture, miscellaneous other vessel injury, air embolism, hydrothorax/pleural effusion, fluid extravasation into the neck, and other nonvessel injury) was classified by two of the authors (K. B. D. and P. H. S.). Two claims with multiple complications were classified as the more serious complication based on the claim summary (*e.g.*, small pneumothorax with large hemothorax was classified as hemothorax).

Complications were further categorized as being related to vascular access or catheter use or maintenance. An *access complication* was defined as occurring during placement of a needle, wire, or catheter into a vessel, such as wire embolus, pneumothorax, and carotid artery puncture/cannulation. A *use/maintenance complication* was defined as occurring during the use of the central or pulmonary artery catheter, such as pulmonary artery rupture, fluid extravasation into the neck, and hydrothorax/pleural effusion. The type of provider who placed the central catheter was categorized (anesthesia

or nonanesthesia) for both access and use complications. For complications of use, the type of provider involved at the time of the complication was also categorized.

Patient injuries, which resulted from the various central catheter complications, were judged as theoretically preventable by ultrasound guidance, pressure waveform monitoring, or chest radiograph, assuming optimal use of these techniques. An injury was judged as possibly preventable by ultrasound guidance if it involved internal jugular venous access resulting in pneumothorax, carotid artery puncture/cannulation, or an access complication occurring as a result of difficult vessel access with multiple attempts at different vessels. The injury was judged as possibly preventable by pressure waveform monitoring if it resulted from arterial cannulation. A complication of subclavian vein catheterization alone (*e.g.*, pneumothorax or subclavian artery injury) was judged as not preventable by ultrasound guidance, due to inconsistent efficacy of ultrasound in clinical trials in catheterization of the subclavian vein.<sup>2,7,11,12</sup> Injuries due to central catheter complications were judged as possibly preventable by chest radiograph in two categories: lack of a chest radiograph or a misread, not read, or inappropriate action taken on the basis of the chest radiograph.

Trends in specific type of injury, access *versus* use complications, and liability characteristics were assessed by dividing the decades into four periods: 1978–1983, 1984–1988, 1989–1993, and 1994–1999. Combining the two earlier periods and the two later periods resulted in a statistical comparison before and after 1989.

### Statistics

Differences between proportions were evaluated using chi-square analysis, the Fisher exact test, and the Z test. Patient characteristics, severity of injury, standard of care, and claim payment for claims for central catheter injuries were compared with all other claims in the Closed Claims database. The proportion of death, standard of care, and claim payment for the most common specific central catheter complications were also compared with the other central catheter complications combined. Payments for settlement and jury award were expressed in dollar amounts adjusted to 1999 dollars using the Consumer Price Index inflation calculator.<sup>\*\*</sup> Because payment did not exhibit a normal distribution, the median and range were used for descriptive purposes. Statistical comparisons of payment distributions were made using the Kolmogorov-Smirnov test.  $P \leq 0.05$  was required for statistical significance. A Bonferroni correction was used to correct for multiple comparisons when comparing the specific central catheter complications to all other central catheter complications combined.

<sup>\*\*</sup> U.S. Department of Labor, Bureau of Labor Statistics Inflation Calculator. Available at: <http://data.bls.gov/cgi-bin/cpicalc.pl>. Accessed November 5, 2003.

**Table 1. Patient Characteristics in Central Catheter vs. All Other Claims in Database (n = 6,449)**

	Central Catheter Claims (n = 110)		All Other Claims (n = 6,339)	
	No.	%*	No.	%*
Age				
0–16 yr	11	11	533	9
17–69 yr	77	75	4,975	82
≥ 70 yr	15	15	544	9
Sex				
Female	58	53	3,722	59
Male	52	47	2,574	41
ASA physical status				
I or II	17	26†	2,873	68†
III, IV, or V	48	74†	1,332	32†
Emergency				
Yes	25	29	1,133	23
No	62	71	3,734	77
Location				
Inpatient	82	99†	3,229	72†
Outpatient	1	1†	1,244	28†
Severity of injury				
Temporary/nondisabling	46	42	3,247	51
Permanent/disabling	12	11†	1,275	20†
Death	52	47†	1,809	29†

\* Percent excludes missing data. †  $P < 0.01$  central catheter claims vs. all other claims.

ASA = American Society of Anesthesiologists.

## Results

### Overview

The database included 110 claims for injuries related to central catheters (1.7% of 6,449 claims). The distribution of year of injury for central catheter claims was 1978–1983 (n = 17), 1984–1988 (n = 31), 1989–1993 (n = 37), and 1994–1999 (n = 19). Six claims could not be classified by year of injury. Compared with all other claims, central catheter claims involved a higher proportion of inpatients and patients with ASA status III–V ( $P \leq 0.01$ ; table 1). Central catheter claims had a high severity

of injury, with a higher proportion of death (47%) compared to other claims (29%;  $P < 0.01$ ; table 1). The proportion of substandard care (45%), proportion of claims with payment (66%), and payment amount (median payment of \$100,750 with range of \$654–\$6,912,000 in central catheter claims) were not significantly different in central catheter claims compared with other claims.

An anesthesiologist inserted the central catheter alone (n = 93) or in conjunction with a surgeon (n = 6) in the majority (90%) of claims. A nonanesthesia provider was involved in 68% (26 of 38 claims) of complications associated with catheter use/maintenance. Payment rates and amount were not influenced by provider.

### Specific Injuries

The most common complications related to central catheters were wire/catheter embolus (n = 20), cardiac tamponade (n = 16), carotid artery puncture/cannulation (n = 16), hemothorax (n = 15), and pneumothorax (n = 14) (table 2). The remaining one fourth of the complications involved hydrothorax/pleural effusion, fluid extravasation in the neck, air embolism, pulmonary artery rupture, a miscellaneous vessel injury, or a non-vessel injury (table 2). There were no significant differences in the proportions of these specific complications between the earlier period (1978–1988) compared with the later period (1989–1999).

**Wire/Catheter Embolus.** Eleven claims involved a wire or wire fragment (all on insertion) and nine claims involved a catheter fragment (five on insertion and four on removal that was not during central venous access). An anesthesiologist was involved in the complication in 14 of the claims, with another healthcare provider (RN, other physician) involved in six of the claims. Wires were visible on postoperative chest radiograph but were not checked by the anesthesiologist in four claims. In four claims, the wire was not visible on the initial chest

**Table 2. Severity of Injury, Standard of Care, and Payment by Type of Central Catheter Complication (n = 110)**

Type of Complication	No.	Death		Substandard Care		Payment Made		Median Payment, \$	Range of Payment, \$
		No.	%	No.	%*	No.	%*		
Wire/catheter embolus	20	1	5†	14	82†	7	85	39,725†	654–132,500
Cardiac tamponade	16	13	81†	5	42	11	69	160,245	34,499–6,912,000
Carotid artery puncture/cannulation	16	5	31	4	31	7	54	40,870	12,975–527,000
Hemothorax	15	14	93†	4	27	8	62	297,000	17,850–1,435,293
Pneumothorax	14	3	21	4	31	4	33	143,250	1,280–208,750
Miscellaneous other vessel injury	8	3	38	2	40	6	75	184,625	1,000–1,717,775
Pulmonary artery rupture	7	7	100†	1	14	3	50	89,600	48,000–152,000
Hydrothorax/pleural effusion	5	2	40	3	100	5	100	110,250	1,604–726,600
Air embolism	4	3	75	2	100	4	100	517,125	304,000–1,076,653
Fluid extravasation in neck	3	1	33	2	67	1	100	444,500	444,500
Other nonvessel injury	2	0	0	0	0	0	0	—	—
All central catheter claims	110	52	47	41	45	66	66	105,500	654–6,912,000

Payments adjusted to 1999 dollars using the Consumer Price Index inflation calculator.

\* Percent excludes missing data. †  $P < 0.05$  compared with other central catheter complications (with Bonferroni correction).



radiograph after catheter placement, but on later films, it was visible.

Wire/catheter embolus was associated with more substandard anesthesia care (82%) than other central catheter claims (table 2). Payments were made to the plaintiff frequently (85%) after wire/catheter embolus, although the median payment was less (\$39,725) than other central catheter claims ( $P < 0.05$ ; table 2).

**Cardiac Tamponade.** Cardiac tamponade was primarily a complication of catheter use/maintenance (13 of 16 claims). In 10 claims, cardiac tamponade became symptomatic 1–5 days postoperatively. In six claims, it became symptomatic in the perioperative period from 5 min to 12 h after central catheter insertion. Claims for cardiac tamponade had a higher proportion of death (81%) than claims for other central catheter injuries combined ( $P < 0.05$ ; table 2). One third ( $n = 5$ ) of the claims involved pediatric patients ranging in age from 2 months to 6 yr. A chest radiograph was definitely obtained after placement of the central catheter in six claims. In two of these claims, the film documented position of the central catheter in the right atrium, but the catheter position was not adjusted by the anesthesiologist.

**Carotid Artery Puncture/Cannulation.** Of the 16 claims for carotid artery puncture/cannulation, 5 resulted in a stroke, 4 resulted in airway obstruction due to a hematoma, 3 involved extra surgery with arterial repair, and 4 resulted in case cancellation. In two claims, the arterial position of the catheter was unrecognized for 22 h or more. Neither ultrasound guidance nor pressure waveform monitoring was used for vessel localization in any of these claims.

**Hemothorax.** Thirteen of 15 claims for hemothorax were a complication of vascular access, with 2 claims a result of delayed perforation postoperatively. The site of insertion, where known, was subclavian vein ( $n = 7$ ) and internal jugular vein ( $n = 6$  [4 right, 1 left, and 1 unknown]). The site of injury, where known, was the subclavian artery ( $n = 5$ ), superior vena cava ( $n = 2$ ), subclavian vein ( $n = 2$ ), and left innominate vein ( $n = 1$ ). A higher proportion of death (93%) occurred in claims for hemothorax compared with other central catheter injuries combined ( $P < 0.05$ ; table 2). No anti-coagulants were administered in any of the cases.

**Pneumothorax.** Of the 14 claims for pneumothorax, the site of insertion of the central catheter was in the subclavian vein alone (6 claims), internal jugular vein alone (3 claims), both the subclavian and internal jugular veins (3 claims), and unknown (2 claims). Claims for pneumothorax had a lower proportion of death (15%) than other central catheter claims combined (table 2).

**Pulmonary Artery Rupture.** Six of seven of the claims related to pulmonary artery rupture were in women, with five of seven occurring during noncardiac surgery. Pulmonary artery rupture claims involved a

higher proportion of elderly patients ( $P < 0.05$  compared with other central catheter claims combined), with five of seven involving patients aged 70 yr and older. The pulmonary artery rupture occurred intraoperatively in four claims and postoperatively in three claims. All claims for pulmonary rupture involved death ( $P < 0.05$  compared with other central catheter claims combined).

**Other Central Catheter Complications.** Profound hypovolemia with hypotension and tachycardia ( $n = 2$ ) and hypoxemia/respiratory distress ( $n = 5$ ) occurring postoperatively were clinical signs of hydrothorax. Fluid extravasation in the neck resulted in airway obstruction ( $n = 2$ ) or hypovolemia ( $n = 1$ ). Air embolism occurred on insertion ( $n = 1$ ), intraoperatively ( $n = 1$ ), or with a disconnect postoperatively ( $n = 2$ ). Miscellaneous vessel injuries included arteriovenous fistula ( $n = 1$ ), aorta injury ( $n = 2$ ), and subclavian artery injury ( $n = 5$ ; resulting in arterial thrombosis [ $n = 2$ ], arterial aneurysm [ $n = 1$ ], and neck hematoma [ $n = 2$ ]). Other nonvessel injuries included phrenic nerve palsy ( $n = 1$ ) and atrial fibrillation ( $n = 1$ ).

#### *Vascular Access versus Catheter Use/Maintenance*

Injuries resulting from catheter use/maintenance complications were more severe than injuries resulting from vascular access complications. The proportion of death was 68% in claims for use complications compared with 36% in claims for access complications ( $P < 0.01$ ). However, there were no differences in appropriateness of care and payment to the plaintiff in complications associated with access compared with those of catheter use/maintenance.

The proportion of vascular access injury increased from 47 to 84% and the proportion of use/maintenance injury decreased (53 to 16%) from 1978 to 1983 compared with 1994–1999 ( $P < 0.05$ ; fig. 1;  $P < 0.002$  comparing before and after 1989).

#### *Preventability of Injuries*

Nearly half of the central catheter claims were judged as possibly preventable by the authors (table 3). Nineteen claims for injuries arising from central catheter complications were judged to be possibly preventable by either ultrasound guidance or pressure waveform monitoring (table 3). Six claims for subclavian artery or aortic injury were judged as possibly preventable by pressure waveform monitoring only. In four additional claims, there was a lack of interval or continuous pressure wave monitoring after placement of the central catheter (two cardiac tamponade, one carotid artery puncture/cannulation, and one hydrothorax/pleural effusion). In nine claims, ultrasound guidance only may have prevented complications related to difficult central catheterization with attempts at multiple sites (table 3). In seven claims, no chest radiograph was taken, and in

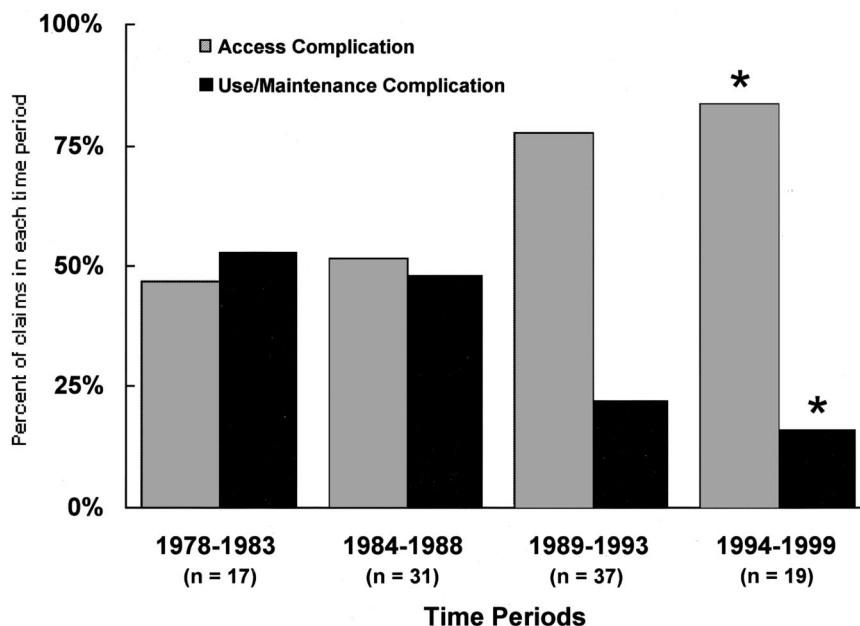


Fig. 1. Proportion of claims or injuries related to vascular access or to catheter use/maintenance over year of injury. A greater proportion of claims from 1989 to 1999 involved access complications. (Six claims could not be classified by year of injury.) \*  $P < 0.05$  1994–1999 compared with 1978–1983 and 1984–1988.

seven claims, the chest radiograph was misread or not read or an inappropriate action was taken on the basis of it (table 3).

## Discussion

The most common complications in closed malpractice claims against anesthesiologists related to central catheters were wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, hemothorax, and pneumothorax. Cardiac tamponade and hemothorax had a higher proportion of death ( $P < 0.05$ ) than the rest of central catheter injuries. Injuries related to central venous access were more common than those related to catheter use/maintenance in the 1990s.

### Methodologic Issues

When interpreting the results, it should be emphasized that closed claims analysis has a number of well-described limitations.<sup>8,9</sup> Because of the lack of denominator data, the Closed Claims database only provides an indirect assessment of the hazards of central catheters and liability risks faced by anesthesiologists. Therefore, we cannot estimate the relative frequency of various central catheter complications. In addition, the closed claims do not indicate or contraindicate use of central venous catheterization. Closed Claims are biased by the presence of more severe and costly injuries because plaintiff attorneys are unlikely to pursue claims with an estimated financial recovery for damage of less than \$50,000.<sup>13</sup> The analysis only evaluated information in the database that was transcribed to the data sheet by the reviewer, who in turn depended on the information contained in the insurance company file. Specific detailed information regarding site of central vein access,

clinical signs, and mechanism of injury is therefore incomplete compared with a prospective study. Because of the time delay from injury to resolution of the claim to appearance within the database (estimated at 3–6 yr), the influence of new technology on liability, such as use of ultrasound guidance during central catheter placement, cannot be fully evaluated. Other limitations of closed claims analysis includes the absence of rigorous comparison groups, partial reliance on data from direct participants rather than impartial observers, and selection of claims in a nonrandom fashion, without control over geographic balance. Although closed claims analysis is useful for generating hypotheses about the mechanism and prevention of injuries related to central catheters, it cannot be used for testing of those hypotheses.

Table 3. Possibly Preventable Injuries Associated with Central Catheter Complications

Possibly preventable by either ultrasound guidance or pressure waveform monitoring (n = 19)
Carotid artery puncture/cannulation (n = 16)
Hemothorax (n = 1)
Wire/catheter embolus (n = 1)
Miscellaneous other vessel injury (n = 1)
Possibly preventable by pressure waveform monitoring only (n = 6)
Miscellaneous other arterial injury (n = 5)
Hemothorax (n = 1)
Possibly preventable by ultrasound guidance only (n = 9)
Hemothorax (n = 4)
Pneumothorax (n = 4)
Miscellaneous other vessel injury (n = 1)
Possibly preventable by chest radiograph (n = 14)
No chest radiograph taken (n = 7)
Carotid tamponade (n = 2)
Wire/catheter embolus (n = 1)
Pneumothorax (n = 4)
Misread, not read, or inappropriate action taken (n = 7)
Cardiac tamponade (n = 4)
Wire/catheter embolus (n = 3)

As a retrospective study, it cannot establish a cause-and-effect relation of previous events nor of changes in claims experience.

### *Central Catheter Complications*

In our review of closed malpractice claims, the most common complications of central catheters were wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, hemothorax, and pneumothorax (table 2). This pattern may reflect the bias inherent in the analysis of malpractice claims for injuries from more substandard care (e.g., wire/catheter embolus) and complications resulting in brain damage or death (e.g., cardiac tamponade and hemothorax). Interestingly, there were no claims for infectious and thrombotic complications, despite the high incidence of these complications reported in the literature.<sup>3,14</sup> Claims for infection and thrombosis from central catheters may be less likely to result in a malpractice claim, or there may be sampling bias in that these claims may be directed at the surgeon/intensivist rather than an anesthesiologist and therefore not captured by our study. Our data are derived from claims against anesthesiologists.

Although claims related to central catheters had a higher proportion of death (47%) than the other claims in the database, the amount of payment to the plaintiff was not different than for the other claims. Payment amount reflects both the standard of care and the severity of injury, in that the highest payments are for severe disabling injuries with substandard care.<sup>8</sup> However, the higher proportion of sicker (ASA physical status III-V) patients in claims related to central catheters, may reduce overall payments for economic damages associated with a diminished life expectancy.

### *Specific Central Catheter Injuries*

**Wire/Catheter Embolus.** Wire/catheter embolus was the most frequent central catheter complication, an injury of low severity, but was associated with more substandard care than other central catheter claims (table 2). Human factors details were generally not available in the closed claims summaries. However, in a fifth of the claims, the anesthesiologist did not check the postoperative chest radiograph where the embolus was clearly visible. The U.S. Food and Drug Administration maintains a Medical Device Reporting system on medical devices that may have malfunctioned or caused a death or serious injury (Maude and MDR databases). Using this database, Scott<sup>15</sup> found that in cases in which the cause of wire/catheter separation could be determined, the problem resulted from human error (e.g., excessive force, shearing the wire/catheter with an insertion needle, puncturing it with a suture needle, inappropriate procedures, or use of incompatible components) rather than a manufacturing defect. Although the Food and Drug Administration databases differ from the closed

claims against anesthesiologists, it is likely human factors were also important in this complication in our database.

**Cardiac Tamponade.** We found that cardiac tamponade was a severe injury, with death in 81% of the claims (table 2), consistent with reports of mortality rates of 47–77% in the literature.<sup>16</sup> The increased proportion of patients aged between 2 months and 6 yr in our claims for cardiac tamponade supports an increased risk of cardiac tamponade with central catheters in pediatric patients.<sup>17</sup> Predisposing factors for cardiac tamponade include catheter tip location within the heart and an angle of the catheter that is not parallel with the wall of the superior vena cava.<sup>18–20</sup> Review of our claims suggests that confirmation of catheter position by chest radiographs, with adjustment of catheter position if intracardiac or with an acute angle of the catheter, might prevent many of the cases of cardiac tamponade.

**Carotid Artery Puncture/Cannulation.** The incidence of carotid artery puncture with internal jugular vein cannulation varies from 1.9 to 9.4%,<sup>5–6,21–23</sup> with higher rates observed with less experienced providers<sup>21</sup> and in infants.<sup>24</sup> Given the high frequency of carotid artery puncture during placement of central catheters,<sup>5,21–22</sup> there are relatively few claims for injuries, probably reflecting the infrequent occurrence of strokes or large hematomas that obstruct airways from carotid punctures.<sup>25</sup> Insertion of a large pulmonary artery sheath or introducer into the carotid artery is thought to be associated with more serious outcomes, including death and brain damage.<sup>26</sup> Although more than half of the claims in our review involved placement of a pulmonary artery introducer, accidental carotid artery cannulation with smaller (e.g., 16- and 18-gauge) catheters was associated with severe complications in some claims.

**Pneumothorax.** Pneumothorax is a frequent complication of central catheter insertion, with an estimated incidence of 1.5–3.1% after subclavian vein catheterization.<sup>2,3,14,21</sup> Pneumothorax is a rare complication of internal jugular vein cannulation but does occur, especially with a low anterior or a posterior approach.<sup>15,21</sup> The relatively low number of claims for pneumothorax, despite the relatively high frequency of occurrence after subclavian vein catheterization, is probably related to both preferential cannulation of the internal jugular vein by anesthesiologists and the generally low severity of injury of a pneumothorax.

### *Vascular Access versus Catheter Use/Maintenance*

The proportion of claims for vascular access injury increased and use/maintenance injury decreased over the decades (fig. 1). The reduced proportion of claims with use/maintenance complications in the 1990s may reflect improvements in catheter materials or anesthesiologist education. Alternately, it may reflect changing legal strategies with claims for use/maintenance compli-



cations directed at intensivists/surgeons/hospitals or a heightened legal awareness of vascular access injuries.

Almost half of the central catheter claims were judged to be possibly preventable by ultrasound guidance, pressure waveform monitoring, or chest radiograph (table 3). There was considerable overlap between pressure waveform monitoring and ultrasound guidance (e.g., prevention of injuries associated with carotid artery puncture/cannulation). Ultrasound guidance has been advocated as a means to reduce mechanical complications associated with central venous catheterization because of improved anatomical orientation,<sup>6,7,14</sup> although these benefits were most consistent for catheterization of the internal jugular vein<sup>5-7</sup> and for novice providers.<sup>11,12</sup> Ultrasound guidance improved visualization of vascular structures, thereby improving the success rate and decreasing access time, but it did not completely prevent accidental insertion of catheters into the carotid artery.<sup>5-7</sup> Pressure waveform monitoring positively identifies venous *versus* arterial access,<sup>22</sup> although misleading results can be obtained if the fluid pathway between the vessel and pressure transducer is compromised.<sup>26</sup> Our results suggest that use of pressure waveform monitoring during placement to prevent accidental arterial cannulation of a large bore catheter may reduce patient injuries. In addition, for patients in whom continuous pressure monitoring is undertaken after catheter insertion, the pressure waveform may provide a warning of catheter malpositioning, such as a right ventricular waveform in the case of a catheter which is advanced into the right ventricle, or the loss of the pressure waveform in the case of a catheter that migrates outside of the blood vessel. Our findings suggest that ultrasound guidance may reduce patient injury by reducing the number of unsuccessful needle insertions in the presence of difficult central venous catheterization. Chest radiographs should be checked postoperatively to rule out a wire/catheter embolus and to avoid dangerous locations of the catheter tip, which are associated with cardiac tamponade, hemothorax, or other vessel injury.

In summary, claims for injuries related to central catheters had a high severity of injury. The most common complications in claims against anesthesiologists were wire/catheter embolus, cardiac tamponade, carotid artery injury, hemothorax, and pneumothorax. In the 1990s, claims for central catheter injuries related to vascular access were more common than claims related to vascular use/maintenance. Patient safety may be improved by use of ultrasound guidance with difficult catheter placement, use of pressure waveform monitoring to prevent accidental arterial cannulation, and checking and acting on chest radiographs after central catheter placement.

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