▼ Review Article

Neurologic Complications of Spinal and Epidural Anesthesia

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Perioperative nerve injuries have long been recognized as a complication of spinal and epidural anesthesia. Fortunately, severe or disabling neurologic complications rarely occur. Cheney et al.[1] examined the American Society of Anesthesiologists Closed Claims database to determine the role of nerve damage in malpractice claims filed against anesthesia care providers. Of the 4,183 claims reviewed, 670 (16%) were for anesthesia-related nerve injury, including 189 claims involving the lumbosacral roots (105 claims) or spinal cord (84 claims). Lumbosacral nerve root injuries having identifiable etiology were associated predominantly with a regional anesthetic technique (92%), and were related to paresthesias during needle or catheter placement or pain during injection of local anesthetic. Major factors associated with spinal cord injury were blocks for chronic pain management and systemic anticoagulation in the presence of neuraxial block.

Neurologic complications associated with neuraxial anesthesia may be divided into two categories: those that are unrelated to the spinal or epidural anesthetic but coincide temporally and those that are a direct result of the regional technique. Postoperative neurologic injury caused by pressure from improper patient positioning or from tightly applied casts or surgical dressings, as well as surgical trauma are often attributed to the neuraxial anesthetic. Marinacci[2] evaluated 542 patients with postoperative neurologic deficits allegedly caused by spinal anesthesia. In only 4 cases were the findings related to the spinal anesthetic (cauda equina syndrome, arachnoiditis, and chronic radiculitis). In the remaining 538 patients, the neurologic deficits exhibited an apparent, but not causal relationship to the spinal anesthetic. Marinacci's study demonstrates the difficulty in reporting the actual incidence, pathogenesis, and prognosis of neurologic dysfunction which occur as a result of spinal or epidural anesthesia.

Risk factors contributing to neurologic deficit after neuraxial anesthesia include spinal cord ischemia (hypothesized to be related to the use of vasoconstrictors or prolonged hypotension), traumatic injury to the spinal cord or nerve roots during needle or catheter placement, infection, and choice of local anesthetic solution.[3-6] The safe conduct of neuraxial anesthesia involves knowledge of the large patient surveys as well as individual case reports of neurologic deficits following neuraxial blocks. Prevention of complications, and early diagnosis and treatment are important factors in management of regional anesthetic risks.

Incidence of Neurologic Complications

The incidence rate of persistent peripheral neuropathy, including persistent paresthesia and sensory or motor dysfunction varied from 0% to 0.08%.[7-10] In addition, within this combined series totaling over 50,000 spinal anesthetics, there was 1 case of cauda equina syndrome presenting with lower extremity weakness and impotence, 1 case of paraplegia (related to a previously undiagnosed spinal cord tumor), and 3 cases of meningitis.[9,10] The incidence of serious neurologic sequelae after epidural anesthesia is also extremely low. There were only 3 patients who suffered permanent lower extremity weakness in a combined series of more than 50,000 epidural anesthetics.[11] The incidence rate of persistent paresthesia (defined as pain, numbness, or weakness after resolution of the spinal anesthetic) ranged from 0% to 0.16%. Although the incidence of neurologic complications associated with thoracic epidural techniques has historically been judged to be higher than that of lumbar placement, Giebler et al.[12] noted only a 0.2% incidence of postoperative radicular pain in 4,185 pa-

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tients undergoing thoracic epidural catheterization; all cases were responsive to catheter removal.

A prospective survey in France evaluated the incidence and characteristics of serious complications related to regional anesthesia.[3] Participating anesthesiologists kept a log of all cases and detailed information of serious complications occurring during or after regional anesthetics. All patients with a neurologic deficit lasting more than 2 days were examined by a neurologist; patients with cauda equina syndrome were evaluated with a computed tomography scan to rule out compressive etiology. A total of 103,730 regional anesthetics, including 40,640 spinal and 30,413 epidural anesthetics, were performed over a 5-month period. The incidence of cardiac arrest and neurologic complications was significantly higher after spinal anesthesia than other types of regional procedures (Table 1). Neurologic recovery was complete within 3 months in 19 of 34 patients with deficits. Needle trauma and local anesthetic neurotoxicity were believed to be the etiology of most neurologic complications. This study showed that the incidence of severe anesthesia-related complications is very low. However, because serious complications were noted to occur even in the presence of experienced anesthesiologists, continued vigilance in patients undergoing neuraxial anesthesia is warranted.

Nerve Injury From Needle and Catheter Placement

Direct needle or catheter-induced trauma rarely results in permanent or disabling neurologic injury. A recent retrospective study of 4,767 spinal anesthetics noted the presence of a paresthesia during needle placement in 298 (6.3%) of patients. Importantly, 4 of the 6 patients with a persistent paresthesia postoperatively complained of a paresthesia during needle placement, identifying elicitation of a paresthesia as a possible risk factor for a persistent paresthesia.[13] In the series by Auroy et al.,[3] two thirds of the patients with neurologic complications experienced pain during needle placement or injection of local anesthetic. In all cases, the neurologic deficit had the same distribution as the elicited paresthesia. In addition, the neurologic injury occurred even though the investigators did not continue to inject in the presence of pain. It is unknown whether clinicians should abandon the procedure if a paresthesia is elicited (rather than replacing the needle), in an effort to decrease the risk of nerve injury.

The passage and presence of an indwelling catheter into the subarachnoid or epidural space presents an additional source of direct trauma. In 1 study, the incidence of paresthesias was 13% with a single-dose and 30% with a continuous catheter spinal anesthetic (CSA) technique.[14] The incidence of postoperative neurologic deficits was also significantly increased following CSA (0.66%) compared with single-dose techniques (0.13%). Laboratory studies have demonstrated demyelination and inflammation adjacent to the catheter tract in both the spinal root and cord of rats following placement of indwelling subarachnoid catheters.[15] The use of a catheter may indirectly contribute to neurologic injury. Poor mixing resulting from very slow injection rates through spinal microcatheters may increase the risk of developing high concentrations of hyperbaric local anesthetics in dependent areas of the spinal canal.[15] This is the presumed mechanism of cauda equina syndrome following continuous spinal anesthesia.[16-18]

Local Anesthetic Toxicity

Neurologic complications after neuraxial anesthesia may be a direct result of local anesthetic toxicity. There is both laboratory and clinical evidence that local anesthetic solutions are potentially neurotoxic and that the neurotoxicity varies among local anesthetic solutions.[5,6,17,19] Although most local anesthetics administered in clinical concentrations and doses do not cause nerve damage,[20] prolonged exposure, high dose, and/or high concentrations of local anesthetic solutions at the spinal roots may result in

Table 1. Number and Incidence of Severe Complications Related to Spinal and Epidural Anesthesia

Neuraxial Technique	Cardiac Arrest	Death	Seizure	Neurologic Injury	Radiculopathy	Cauda Equina Syndrome	Paraplegia
Spinal	26*	6	0	24*	19*	5	0
n = 40,640	(3.9–8.9)	(0.3–2.7)	(0–0.9)	(3.5–8.3)	(2.6–6.8)	(0.1–2.3)	(0–0.9)
Epidural	3	0	4	6	5	0	1
n = 30,413	(0.2–2.9)	(0–1.2)	(0.4–3.4)	(0.4–3.6)	(0.5–3.8)	(0–1.2)	(0–1.8)

NOTE. Data presented are number and (95% confidence interval).
*Spinal versus epidural ($P < .05$).
Adapted and reprinted with permission from Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K. Serious complications related to regional anesthesia. *Anesthesiology.* Vol 87, p 479-486.[3]

permanent neurologic deficits.[21] For example, cauda equina syndrome has been reported after single-dose and CSA, intrathecal injection during intended epidural anesthesia, and repeated intrathecal injection after failed spinal block with lidocaine.[3,17,22] Presumably, injection (or reinjection) results in high concentrations of local anesthetic within a restricted area of the intrathecal space and causes neurotoxic injury. In histopathologic, electrophysiologic, and neuronal cell models, lidocaine and tetracaine appear to have a greater potential for neurotoxicity than bupivacaine at clinically relevant concentrations.[23] In the study by Auroy et al.,[3] 75% of the neurologic complications after uneventful (atraumatic) spinal anesthesia occurred in patients who received hyperbaric lidocaine, including 1 patient who received 350 mg over 5 hours with a 5% lidocaine infusion. Drasner[24] has recommended a maximum dose of 60 mg lidocaine and the avoidance of epinephrine to prolong lidocaine spinal anesthesia. In addition, many clinicians recommend using isobaric solutions to reduce the risk of nonuniform distribution within the intrathecal space. Attention to patient positioning, total local anesthetic dose, and careful neurologic examination (evaluating for preferential sacral block) will assist in the decision to inject additional local anesthetic in the face of a patchy or failed block.

Transient Neurologic Symptoms

Transient neurologic symptoms (TNS) were first formally described in 1993. Schneider et al.[4] reported 4 cases of severe radicular back pain occurring after resolution of hyperbaric lidocaine spinal anesthesia. All 4 patients had undergone surgery in the lithotomy position. No sensory or motor deficits were detected on examination, and the symptoms resolved spontaneously within several days. Multiple laboratory and clinical studies have been performed in an attempt to define the etiology, clinical significance, and risk factors associated with TNS. However, our understanding remains incomplete.

The incidence rate of TNS has ranged between 0% and 37%,[25,26] and is dependent on anesthetic, surgical, and probably undefined patient factors. A prospective randomized study reported a 16% incidence rate of TNS in patients receiving either hyperbaric 5% lidocaine with epinephrine or 2% isobaric lidocaine. However, no patient receiving 0.75% hyperbaric bupivacaine developed TNS.[25] In addition, the incidence was higher among patients positioned with knees or hips flexed (genitourinary, arthroscopy) than patients positioned supine (herniorrhaphy), presumably because the flexion results in additional stretch on the nerve roots. A subsequent study comparing the incidence of TNS in knee arthroscopy patients undergoing spinal anesthesia with 50 mg lidocaine in 2%, 1%, and 0.5% concentrations also failed to note a concentration effect; the incidence was similar in all groups.[27] The lack of concentration[27] or dose effect[28] suggests that neurotoxicity is not the etiology of TNS, but does not rule out an alternative intrathecal source. Neurophysiologic evaluation in volunteers during TNS did not reveal abnormalities in somatosensory evoked potentials, electromyography, or nerve conduction studies (J.E. Pollock and J.M. Neal: personal communication, February 1999.)

A large multicenter epidemiologic study involving 1,863 patients was recently performed to identify potential risk factors for TNS.[28] The incidence of TNS with lidocaine (11.9%) was significantly higher than that with tetracaine (1.6%) or bupivacaine (1.3%). The pain was described as severe in 30% of patients and resolved within a week in more than 90% of cases. Outpatient status, obesity, and lithotomy position also increase the risk of TNS for patients receiving lidocaine. This suggests that the risk of TNS is high among outpatients in the lithotomy position (24.3%) and low for inpatients having surgery in positions other than lithotomy (3.1%). However, these variables were not risk factors with tetracaine or bupivacaine. The authors also reported that neither gender, age, history of back pain or neurologic disorder, lidocaine dose/concentration, spinal needle/size, aperture direction, nor addition of epinephrine increased the risk of TNS (Table 2). A previous study has identified the addition of phenylephrine as a risk factor for TNS with tetracaine spinal anesthesia.[29]

The clinical significance of TNS is unknown. Although many anesthesiologists believe that the reversible radicular pain is on one side of a continuum leading to irreversible cauda equina syn-

Table 2. Factors That Did Not Increase the Risk of Developing Transient Neurologic Symptoms After Lidocaine Spinal Anesthesia

Gender
Age (<60 y *v* 60+ y)
Preexisting neurologic disorder or back pain
Needle type (Quincke *v* Pencil point)
Needle size (22 gauge *v* 24–25 gauge *v* 26–27 gauge)
Bevel direction during injection (caudad *v* cephalad *v* lateral)
Lidocaine dose (<50 mg *v* 51–74 mg *v* >75 mg)
Intrathecal epinephrine
Intrathecal opioid
Intrathecal dextrose
Paresthesia during needle placement

Adapted and reprinted with permission from Freedman JM, Li D, Drasner K, Jaskela MC, Larsen B, Wi S. Transient neurologic symptoms after spinal anesthesia. An epidemiologic study of 1863 patients. *Anesthesiology*. Vol 89, pp 633-641.[28]

drome, there are no data to support this concept. It is important to distinguish between factors associated with serious neurologic complications, such as cauda equina syndrome, and transient symptoms when making recommendations for the clinical treatment of patients. For example, increasing the concentration/dose of lidocaine and adding epinephrine increases the risk of irreversible neurotoxicity, but has little effect on the risk of TNS. Therefore, the clinician must determine the appropriate intrathecal solution, including adjuvants, given the surgical duration and intraoperative position for each individual patient.

Anterior Spinal Artery Syndrome

The blood supply to the spinal cord is precarious because of the relatively large distances between the radicular vessels. Systemic hypotension or localized vascular insufficiency with or without a spinal anesthetic may produce spinal cord ischemia resulting in flaccid paralysis of the lower extremities or anterior spinal artery syndrome.[11] Characteristics of anterior spinal artery syndrome, spinal abscess, and spinal hematoma are reported in Table 3. The use of local anesthetic solutions containing epinephrine or phenylephrine theoretically may produce local cord ischemia, especially in patients with microvascular disease.[5,19] However, most animal studies fail to show a significant decrease in spinal cord blood flow,[23] and large studies have failed to identify the use of vasoconstrictors as a risk factor for temporary or permanent deficits.[7,10] Most presumed cases of vasoconstrictor-induced neurologic deficits have been reported as single case reports, often with several other risk factors present.[3,30] A recent investigation by Sakura et al.[29] noted that the addition of phenylephrine increased the risk of TNS in patients undergoing tetracaine spinal anesthesia. It is important to note that no patient in the study by Sakura et al. had sensory or motor deficits and that currently there is no definitive evidence that local anesthetic-related injury is related to TNS. The actual risk of significant neurologic ischemia in patients administered local anesthetic solutions containing vasoconstrictors, therefore, remains unknown.

Spinal Hematoma

The actual incidence of neurologic dysfunction resulting from hemorrhagic complications associated with neuraxial blocks is unknown. However, the incidence cited in the literature is estimated to be less than 1 in 150,000 epidural and less than 1 in 220,000 spinal anesthetics.[31] Vandermeulen et al.[32] reported 61 cases of spinal hematoma associated with epidural or spinal anesthesia. In 42 of the 61 patients (68%), the spinal hematomas associated with neuraxial blocks occurred in patients with evidence of hemostatic abnormality. Twenty-five of the patients had received intravenous or subcutaneous heparin, whereas an additional five patients were presumably administered heparin, as they were undergoing a vascular surgical procedure. In addition, 12 patients had evidence of coagulopathy or were treated with antiplatelet medications, oral anticoagulants, thrombolytics, or dextran 70 immediately before or after the spinal or epidural anesthetic. Regional technique was also noted. A spinal anesthetic was performed in 15 patients. The remaining 46 patients received an epidural anesthetic, including 32 patients with an indwelling catheter. In 15 of these 32 patients, the spinal hematoma occurred immediately after the removal of the epidural catheter. (Nine of these catheters were removed during intervals with therapeutic levels of heparinization.) These results suggest that catheter removal is not entirely atraumatic, and the patient's coagulation status at the time of catheter removal is perhaps as critical as that at the time of catheter

Table 3. Differential Diagnosis of Spinal Abscess, Spinal Hematoma, and Anterior Spinal Artery Syndrome

	Spinal Abscess	Spinal Hematoma	Anterior Spinal Artery Syndrome
Age of patient	Any age	50% over 50 years	Elderly
Previous history	Infection*	Anticoagulants	Arteriosclerosis/hypotension
Onset	1–3 days	Sudden	Sudden
Generalized symptoms	Fever, malaise, back pain	Sharp, transient back and leg pain	None
Sensory involvement	None or paresthesias	Variable, late	Minor, patchy
Motor involvement	Flaccid paralysis, later spastic	Flaccid paralysis	Flaccid paralysis
Segmental reflexes	Exacerbated*—later obtunded	Abolished	Abolished
Myelogram/CT scan	Signs of extradural compression	Signs of extradural compression	Normal
Cerebrospinal fluid	Increased cell count	Normal	Normal
Laboratory data	Rise in sedimentation rate	Prolonged coagulation time*	Normal

*Infrequent findings.
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placement. Return of neurologic function was partial or good in only 38% of patients and tended to occur in patients who underwent laminectomy within 8 hours of diagnosis of spinal hematoma.

Oral Anticoagulants

Few data exist regarding the risk of spinal hematoma in patients with indwelling epidural catheters who are anticoagulated with warfarin. The optimal duration of an indwelling catheter and the timing of its removal also remain controversial. Odoom and Sih[33] performed 1,000 continuous lumbar epidural anesthetics in vascular surgical patients who were receiving oral anticoagulants *preoperatively.* The thrombotest (a test measuring factor IX activity) was decreased (though not below 10% activity) in all patients before needle placement. Heparin was also administered intraoperatively. Epidural catheters remained in place for 48 hours postoperatively. There were no neurologic complications. Although these results are reassuring, the obsolescence of the thrombotest as a measure of anticoagulation combined with the unknown coagulation status of the patients at the time of catheter removal limits the usefulness of these results. Therefore, except in extraordinary circumstances, spinal or epidural needle/catheter placement and removal should not be performed in fully anticoagulated patients.

There were also no symptomatic spinal hematomas in 192 patients receiving postoperative epidural analgesia in conjunction with low-dose warfarin after total knee arthroplasty. Patients received warfarin, starting on the postoperative day, to prolong the prothrombin time (PT) to 15.0 to 17.3 seconds (normal, 10.9 to 12.8 seconds), corresponding to an international normalized ratio (INR) of 2.0 to 3.0. Epidural catheters were left indwelling 37 ± 15 hours (range, 13 to 96 hours). Mean PT at the time of epidural catheter removal was 13.4 ± 2 seconds (range, 10.6 to 25.8 seconds). This study documents the relative safety of low-dose (3 to 5 mg/d) warfarin anticoagulation in patients with an indwelling epidural catheter. A large variability in patient response to warfarin was also noted, demonstrating the need for close monitoring of the coagulation status.[34]

Wu and Perkins[35] reviewed the records of 459 patients who underwent orthopaedic surgical procedures under spinal or epidural anesthesia, including 412 patients who received postoperative epidural analgesia. All patients were anticoagulated with warfarin postoperatively, although the dose of warfarin administered was not recorded. Mean duration of epidural analgesia was 43.6 ± 12.5 hours (range, 5 to 118 hours). Prothrombin time at the time of epidural catheter removal was 14.1 ± 3.2 seconds (normal, 9.6 to 11.1 seconds), corresponding to an INR of 1.4. Patients who had warfarin thromboprophylaxis initiated preoperatively had significantly higher PTs at the time of catheter removal than patients who had received postoperative warfarin only. There was no evidence of spinal hematoma. These results suggest that patients receiving oral anticoagulants may safely undergo regional techniques, even when thromboprophylaxis is initiated preoperatively.

Intravenous and Subcutaneous Standard Heparin

The safety of neuraxial techniques in combination with intraoperative heparinization is well documented, provided that no other coagulopathy is present. In a study involving more than 4,000 patients, Rao and El-Etr[36] demonstrated the safety of indwelling spinal and epidural catheters during systemic heparinization during vascular surgery. However, the heparin was administered at least 60 minutes after catheter placement, level of anticoagulation was closely monitored, and the indwelling catheters were removed at a time when circulating heparin levels were relatively low. A subsequent study in the neurologic literature by Ruff and Dougherty[37] reported spinal hematomas in 7 of 342 patients (2%) who underwent a diagnostic lumbar puncture and subsequent heparinization. Traumatic needle placement, initiation of anticoagulation within 1 hour of lumbar puncture, or concomitant aspirin therapy were identified as risk factors in the development of spinal hematoma in anticoagulated patients.

Low-dose subcutaneous standard (unfractionated) heparin is administered for thromboprophylaxis in patients undergoing major thoracoabdominal surgery and in patients at increased risk of hemorrhage with oral anticoagulant or low–molecular-weight heparin (LMWH) therapy. A review of the literature by Schwander and Bachmann[38] noted no spinal hematomas in more than 5,000 patients who received subcutaneous heparin in combination with spinal or epidural anesthesia. There are only 3 cases of spinal hematoma associated with neuraxial blocks in the presence of low-dose heparin—2 of which involved a continuous epidural anesthetic technique.[39-41]

Low–Molecular-Weight Heparin

Extensive clinical testing and utilization of LMWH in Europe over the last 10 years has suggested that there was not an increased risk of spinal hematoma in patients undergoing neuraxial anesthesia while

receiving LMWH thromboprophylaxis perioperatively.[32,42] However, in the 5 years since the release of LMWH for general use in the United States in May 1993, more than 40 cases of spinal hematoma associated with neuraxial anesthesia administered in the presence of perioperative LMWH prophylaxis have been reported to the manufacturer.[43] Many of these events occurred when LMWH was administered intraoperatively or early postoperatively to patients undergoing continuous epidural anesthesia and analgesia (Table 4). Concomitant antiplatelet therapy was present in several cases. The apparent difference in incidence in Europe compared with the United States may be a result of a difference in dose and dosage schedule. For example, in Europe the recommended dose of enoxaparin is 40 mg once daily (with LMWH therapy initiated 12 hours preoperatively), rather than 30 mg every 12 hours. However, timing of catheter removal may also have an impact. It is likely that the lack of a trough in anticoagulant activity associated with twice daily dosing resulted in catheter removal occurring during significant anticoagulant activity. The incidence of spinal hematoma in patients undergoing neuraxial block in combination with LMWH has been estimated at 1 in 40,800 spinal anesthetics and 1 in 3,100 continuous epidural anesthetics.[44] It must be noted that these values are estimates, not actual frequency rates, and therefore must be interpreted with caution. In addition, there are no data to suggest that the risk of spinal hematoma is increased with certain LMWH formulations.[43]

Table 4. Patients With Spinal Hematoma Following Continuous Neuraxial Anesthesia/Analgesia in Combination With LMWH (n = 26)

	No. of Patients
Initiation of LMWH dosing	
Preoperative	4
≤12 h postoperatively	11
24 h postoperatively	5
Unknown	6
LMWH administered with catheter indwelling*	17
Concomitant antiplatelet/anticoagulant medications	
Antiplatelet therapy	7
Warfarin	2
Multiple medications	3
Onset of symptoms†	
Catheter indwelling	4
Within hours of catheter removal	7
More than 12 h after catheter removal	10
Undetermined	5

*A minimum of 17 patients received LMWH with an indwelling neuraxial catheter. Only 2 patients had documented catheter removal occur before initiation of LMWH, including 1 patient who received warfarin in the postanesthesia care unit.

†Four patients reported minor deficits before catheter removal, including 2 patients who became acutely paraplegic on catheter removal. Although paralysis occurred shortly after catheter removal in at least 7 patients, 24 h or more often elapsed between catheter removal and the onset of neurological dysfunction.

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Antiplatelet Medications

Orthopaedic and vascular patients often receive antiplatelet medications (i.e., aspirin, ibuprofen, naproxen) perioperatively for analgesia and thromboprophylaxis. Although Vandermeulen et al.[32] implicated antiplatelet therapy in 3 of the 61 cases of spinal hematoma occurring after spinal or epidural anesthesia, several large studies have demonstrated the relative safety of neuraxial blocks in both obstetric and surgical patients receiving these medications.[45-47] In a prospective study involving 1,000 patients, Horlocker et al.[47] reported that preoperative antiplatelet therapy did not increase the incidence of blood present at the time of needle/catheter placement *or* removal, suggesting that trauma incurred during needle or catheter placement is neither increased nor sustained by these medications. There was no difference in the incidence of traumatic needle placement among the various antiplatelet agents. The clinician should be aware of the possible increased risk of spinal hematoma in patients receiving antiplatelet medications who undergo subsequent heparinization.

Anesthetic Management of the Anticoagulated Patient

The decision to perform spinal or epidural anesthesia/analgesia and the timing of catheter removal in a patient receiving thromboprophylaxis should be made on an individual basis, weighing the small, though definite risk of spinal hematoma with the benefits of regional anesthesia for a specific patient. Alternative anesthetic and analgesic techniques exist for patients considered to be at an unacceptable risk. The patient's coagulation status should be optimized at the time of spinal or epidural needle or catheter placement, and the level of anticoagulation must be monitored during the period of epidural catheterization (Table 5). It is important to note that patients respond with variable sensitivities to anticoagulant medications. Indwelling catheters should not be removed in the presence of therapeutic anticoagulation, because this appears to significantly increase the risk of spinal hematoma.[32] In addition, communication between clinicians involved in the perioperative management of patients receiving anticoagulants for thromboprophylaxis is essential to decrease the risk of serious hemorrhagic complications.

Except in extraordinary circumstances, the risk of spinal hematoma outweighs the potential benefits of neuraxial blocks in patients who have known

Table 5. Pharmacologic Activities of Anticoagulants and Antiplatelet Agents

Agent	Effect on Coagulation Variables (PT)	Effect on Coagulation Variables (APTT)	Time to Peak Effect	Time to Normal Hemostasis After Discontinuation	Comments
Intravenous heparin	↑	↑↑↑	Minutes	4–6 h	Monitor ACT, APTT, delay heparinization for 1 hour after needle placement.
Subcutaneous heparin	↑	↑↑	40–50 min	4–6 h	aPTT may remain normal; anti-Xa activity reflects degree of anticoagulation.
LMWH	—	—	3–5 h	12+ h	Anti-Xa activity not monitored; use with caution in patients receiving epidural analgesia.
Warfarin	↑↑↑	↑	4–6 d (Less with loading dose)	4–6 d	Monitor PT in patients with indwelling catheters.
Antiplatelet agents					Bleeding time not reliable predictor of platelet function.
Aspirin	—	—	Hours	5–8 d	
Other NSAIDs	—	—		1–3 d	

PT, prothrombin time; aPTT, activated partial thromboplastin time; ACT, activated clotting time; ↑, clinically insignificant increase; ↑↑, possibly clinically significant increase; ↑↑↑, clinically significant increase; NSAIDs, nonsteroidal anti-inflammatory drugs.
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coagulopathies, have significant thrombocytopenia, or have received thrombolytic therapy within the previous 24 hours.[48]

Anesthetic management of patients anticoagulated perioperatively with warfarin is dependent on dosage and timing of initiation of therapy. The PT and INR of patients on chronic oral anticoagulation will require 3 to 5 days to normalize after discontinuation of the anticoagulant therapy. Documentation of the patient's normal coagulation status should be achieved before implementation of neuraxial block. Patients receiving warfarin therapy during epidural analgesia should have their PT and INR monitored on a daily basis and checked before catheter removal if the initial dose of warfarin was more than 36 hours beforehand. There is no definitive recommendation for removal of neuraxial catheters in patients with therapeutic levels of anticoagulation; the trauma associated with catheter removal must be compared to the ongoing trauma produced by an indwelling catheter in an anticoagulated patient, as well as the degree and duration of anticoagulation.[49]

Patients may safely undergo neuraxial block in combination with standard heparin. The concurrent use of medications that affect other components of the clotting mechanisms may increase the risk of bleeding complications for patients receiving standard heparin. Intravenous heparin administration should be delayed for 1 hour after needle placement. Indwelling catheters should be removed 1 hour before a subsequent heparin administration or 2 to 4 hours after the last heparin dose. Evaluation of the coagulation status may be appropriate before catheter removal in patients who have shown enhanced response or are on higher doses of heparin. Although the occurrence of a bloody or difficult needle placement may increase risk, there are no data to support mandatory cancellation of a case should this occur. Prolonged therapeutic anticoagulation appears to increase risk of spinal hematoma formation, especially if combined with other anticoagulants or thrombolytics. Therefore, neuraxial blocks should be avoided in this clinical setting. There is no contradiction to use of neuraxial techniques during subcutaneous standard heparin. The risk of neuraxial bleeding may be reduced by delay of the heparin injection until after the block and may be increased in debilitated patients or after prolonged therapy.[50]

Anesthesiologists in the United States can draw on the European experience to develop their own practice guidelines for the management of patients undergoing spinal and epidural blocks while receiving perioperative LMWH. Because anti-Xa activity is not predictive of the risk of bleeding, monitoring of the anti-Xa level is not recommended. In addition, concomitant administration of medications affecting hemostasis, such as antiplatelet drugs, standard heparin, or dextran should be avoided. A spinal anesthetic may be the anesthetic of choice for patients receiving LMWH preoperatively. Needle placement should occur at least 10 to 12 hours after the LMWH dose. However, patients receiving higher "treatment" doses of LMWH (e.g., enoxaparin 1 mg/kg twice daily) will require longer delays (24 hours). Neuraxial techniques should be avoided in patients administered a dose of LMWH 2 hours preoperatively (general surgery patients), because needle placement occurs during peak anticoagulant activity. Patients with postoperative initiation of LMWH thromboprophylaxis may safely undergo single-dose and continuous catheter techniques. The first dose of LMWH should be administered no

earlier than 24 hours postoperatively. In addition, indwelling catheters should be removed before initiation of LMWH thromboprophylaxis. The decision to implement LMWH thromboprophylaxis in the presence of an indwelling catheter must be made with care. Extreme vigilance of the patient's neurologic status is warranted. For any LMWH prophylaxis regimen, timing of catheter removal is of paramount importance. Catheter removal should be delayed for at least 10 to 12 hours after a dose of LMWH. Subsequent dosing should not occur for at least 2 hours after catheter removal.[43]

Antiplatelet drugs, by themselves, appear to represent no added significant risk for the development of spinal hematoma in patients having epidural or spinal anesthesia. It is not necessary to discontinue antiplatelet medications or assess platelet function prior to neuraxial anesthesia. However, the concurrent use of medications that affect other components of the clotting mechanisms, such as oral anticoagulants, standard heparin, and LMWH, may increase the risk of bleeding complications for patients receiving antiplatelet agents. Assessment of platelet function prior to performance of neuraxial block is not recommended. However, preoperative assessment of the patient to identify alterations of health that might contribute to bleeding is crucial.[51] The relative risk of other antiplatelet agents such as ticlopidine and clopidogrel remains undetermined at this time.

The patient should be closely monitored in the perioperative period for signs of cord ischemia. If spinal hematoma is suspected, the treatment of choice is immediate decompressive laminectomy. Recovery is unlikely if surgery is postponed for more than 10 to 12 hours—less than 40% of the patients in the series by Vandermeulen et al.[32] had partial or good recovery of neurologic function.

Meningitis and Spinal Abscess

Bacterial infection of the neuraxis may present as meningitis or cord compression secondary to abscess formation. The infectious source can be exogenous due to contaminated equipment or medication or endogenous secondary to a bacterial source in the patient seeding to the remote site of needle or catheter insertion. In addition, indwelling catheters may be colonized from a superficial site and subsequently serve as a wick for spread of infection from the skin to the epidural or intrathecal space. An alternative mechanism may be contamination of the epidural or intrathecal space with viridans streptoccoci from the operator's buccal mucosa. Schneeberger et al.[52] recently reported 4 cases of iatrogenic meningitis following spinal anesthesia occurring over a 4-year period. The patients typically presented 24 hours postoperatively with a severe headache (2 received an epidural blood patch). All cases involved the same anesthesiologist, who had a history of recurrent pharyngitis and did not wear a mask during the procedure. As a result of this cluster of cases, infection control measures, including the wearing of face masks, were introduced. While there is some evidence that face masks reduce the spread of viridans streptococci, it has not been shown that face masks will reduce the incidence of neuraxial infection. There are currently no universal guidelines or recommendations for their use during regional anesthetic procedures.

Although individual cases have been reported in the literature, serious neuraxial infections such as arachnoiditis, meningitis, and abscess following spinal or epidural anesthesia are rare. In a combined series of more than 65,000 spinal anesthetics, there were only 3 cases of meningitis. A similar review of approximately 50,000 epidural anesthetics failed to disclose a single epidural or intrathecal infection.[11] Few data suggest that spinal or epidural anesthesia during bacteremia is a risk factor for infection of the neuraxis. Although the authors of the previous studies did not report how many patients were febrile during administration of the spinal or epidural anesthetic, a significant number of the patients included in these studies underwent obstetric or urologic procedures. Therefore, it is likely that some patients had bacteremia after (and perhaps during) needle or catheter placement. Despite the apparent low risk of central nervous system infection following regional anesthesia, some anesthesiologists have long considered sepsis to be a relative contraindication to the administration of spinal or epidural anesthesia. This impression is based mainly on anecdotal reports and conflicting laboratory and clinical investigations.

Meningitis After Dural Puncture

Dural puncture has long been considered a risk factor in the pathogenesis of meningitis. Exactly how bacteria cross from the blood stream into the spinal fluid is unknown. The presumed mechanisms include introduction of blood into the intrathecal space during needle placement and disruption of the protection provided by the blood–brain barrier. However, lumbar puncture is often performed in patients with fever or infection of unknown origin. If dural puncture during bacteremia results in meningitis, definite clinical data should exist. In fact, clinical studies are few, and often are antiquated (Table 6).

Initial laboratory and clinical investigations were

Table 6. Meningitis After Dural Puncture

Author (year)	No. Patients	Population	Microorganism(s)	Patients With Spontaneous Meningitis	Patients With Lumbar Puncture-induced Meningitis	Comments
Wegeforth (1919)	93	Military personnel	*Neisseria meningitidis* *Streptococcus pneumoniae*	38 of 93 (41%)	5 of 93, including 5 of 6 bacteremic patients	Lumbar punctures performed during meningitis epidemics
Pray (1941)	416	Pediatric with bacteremia	*Streptococcus pneumoniae*	86 of 386 (22%)	8 of 30 (27%)	80% of patients with meningitis <2 y of age
Eng (1981)	1,089	Adults with bacteremia	Atypical and typical bacteria	30 of 919 (3.3%)	3 of 170 (1.8%)	Atypical organisms responsible for lumbar puncture induced meningitis
Teele (1981)	271	Pediatric with bacteremia	*Streptococcus pneumoniae* *Neisseria meningitidis* *Haemophilus influenzae*	2 of 31 (8.7%)	7 of 46 (15%)*	All cases of meningitis occurred in children <1 y of age. Antibiotic therapy reduced risk
Smith (1986)	11	Preterm with neonatal sepsis	NA (No cases of meningitis)	0%	0%	

*Significant association ($P < .001$). Spontaneous meningitis, concurrent bacteremia and meningitis (without a preceding lumbar puncture). Lumbar puncture-induced meningitis, positive blood culture with sterile CSF on initial examination subsequent positive CSF culture (same organism present in blood).

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performed more than 80 years ago. Weed et al.[53] found that lumbar or cisternal puncture performed during septicemia in multiple animal models (produced by IV injection of a gram-negative bacillus) invariably resulted in a fatal meningitis. Wegeforth and Latham[54] reported their clinical observations on 93 patients suspected of having meningitis who received a diagnostic lumbar puncture. Blood cultures were taken simultaneously. The diagnosis was confirmed in 38 patients. The remaining 55 patients had normal cerebrospinal fluid (CSF). However, 6 of these 55 patients were bacteremic at the time of lumbar puncture. Five of the 6 bacteremic patients subsequently developed meningitis. It was implied, but not stated, that patients with both sterile blood and CSF cultures did not develop meningitis. Unfortunately, these lumbar punctures were performed during 2 epidemics of meningitis that occurred at a military installation, and it is possible that some (or all) of these patients may have developed meningitis without lumbar puncture. These 2 historical studies provided support for the claim that lumbar puncture during bacteremia was a risk factor for meningitis.

In a recent study similar to that by Weed et al., Carp and Bailey[55] investigated the association between meningitis and dural puncture in bacteremic rats. Twelve of 40 rats subjected to cisternal puncture with a 26-gauge needle during *Escherichia coli* bacteremia subsequently developed meningitis. In addition, bacteremic animals not undergoing dural puncture and animals undergoing dural puncture in the absence of bacteremia did not develop meningitis. Meningitis occurred only in animals with a blood culture result of greater than 50 colony forming units/mL at the time of dural puncture. Treatment of a group of bacteremic rats with a single dose of gentamicin immediately prior to cisternal puncture apparently eliminated the risk of meningitis, as none of these animals developed infection.

This study shows that dural puncture in the presence of bacteremia is associated with the development of meningitis in rats and that antibiotic treatment before dural puncture reduces this risk. Unfortunately, this study did not include a group of animals that were treated with antibiotics *after* dural puncture. Because many surgeons defer antibiotic therapy until after cultures are obtained, the actual clinical scenario remains unstudied. There are several other limitations to this study. While *E. coli* is a common cause of bacteremia, it is an uncommon cause of meningitis. In addition, the authors knew the sensitivity to the bacteria injected, allowing for appropriate antibiotic coverage. The authors also performed a cisternal puncture (rather than lumbar puncture) and used a 26-gauge needle, producing a relatively large dural defect in the rat compared with dural puncture with spinal needles in humans. Finally, no local anesthetic was injected. Local anesthetic solutions are typically bacteriostatic, which may reduce the risk of meningitis in normal clinical settings. These results may not apply to administration of epidural anesthesia in the febrile patient

(which involves placement of an indwelling catheter).

Epidural Abscess After Epidural Anesthesia

Several relevant studies have specifically examined the risk of epidural abscess in patients receiving epidural anesthesia and/or analgesia. Bader et al.[56] investigated the use of regional anesthesia in women with chorioamnionitis. Three hundred nineteen women were identified from a total of 10,047 deliveries. Of the 319 women, 100 had blood cultures taken on the day of delivery. Eight of these had blood cultures consistent with bacteremia. Two hundred ninety-three of the 319 patients received a regional anesthetic; in 43 patients antibiotics were administered before needle or catheter placement. No patient in the study, including those with documented bacteremias, had infectious complications. In addition, mean temperatures and leukocyte counts in patients who received blood cultures showed no significant differences between bacteremic and nonbacteremic groups. These authors continue to administer spinal and epidural anesthesia in patients with suspected chorioamnionitis because they believe the potential benefits of regional anesthesia outweigh the theoretical risk of infectious complications.

Strafford et al.[57] reviewed 1,620 pediatric patients who received epidural analgesia for postoperative pain relief. Epidural catheters were left indwelling for a median of 2 days (range, 0 to 8 days). No patient developed an epidural abscess. One patient with osteosarcoma metastatic to spine, chest wall, and lungs became febrile after 10 days of epidural catheterization. When the catheter was removed, culture demonstrated candidal contamination. A second thoracic epidural catheter was placed 4 days later to provide analgesia. Two weeks later, she developed an acute sensory and motor block at T2. Magnetic resonance images (MRI) showed an epidural fluid collection; an emergent laminectomy was performed. A large amount of necrotic tumor as well as fluid containing *C. tropicalis* was present in the epidural space. Her neurologic deficits resolved postoperatively. Three additional patients with chronic pain syndromes were evaluated for epidural infection; all were negative. The authors concluded that for terminally ill patients, the risk of infection with long-term epidural catheterization is acceptable, but recommended careful monitoring to avoid serious neurologic sequelae.

The safety of epidural analgesia in 75 patients admitted to the intensive care unit was prospectively evaluated by Darchy et al.[58] There were no epidural abscesses. However, 5 of 9 patients with positive cultures of the catheter insertion site also had positive catheter tip cultures (epidural catheter infection); *Staphylococcus epidermidis* was the most commonly cultured microorganism. Local infection of the catheter site was treated with catheter removal, but antibiotic therapy was not specifically prescribed. Concomitant infection at other sites, antibiotic prophylaxis, and duration of epidural analgesia were not risk factors for epidural analgesia-related infections. The authors noted that the presence of both erythema and local discharge is a strong predictor of local and epidural catheter infection.

Chronic epidural catheterization in cancer patients is also a potential risk for epidural infection. Du Pen et al.[59] studied 350 patients in whom permanent (tunneled) epidural catheters were placed. The authors examined 3 areas of the catheter track for evidence of infection: exit site, superficial catheter track, and epidural space. The rate of epidural and deep track catheter-related infections was one in every 1,702 days of catheter use in the 19 patients who developed deep track[8] or epidural[15] infections. (Four of the 19 patients had both deep track and epidural involvement.) Bacteria cultured were most frequently skin flora. All 19 patients with deep infections were treated with catheter removal and antibiotics; none required surgical decompression or debridement. Catheters were replaced in 15 of the 19 patients who requested them after treatment with no recurrent infections. The authors state recommendations similar to Strafford et al.; long-term epidural catheterization is safe when patients are carefully monitored for signs of infection and receive prompt treatment when the diagnosis is established.

Epidural anesthesia and analgesia in a patient with a known systemic or localized infection remain controversial. Jakobsen et al.[60] retrospectively reviewed the records of 69 patients with abscesses or wound infections who underwent epidural catheter placement for surgical debridement over a 7-year period. Several patients had more than one catheter inserted. Catheters were left indwelling for a mean of 9 days. On 12 occasions (8 patients), the catheter was removed because of local infection. None of the patients had signs or symptoms of neuraxial infection. The authors concluded that epidural anesthesia is relatively safe for patients requiring repeated surgical treatment of localized infection. In contrast, Bengtsson et al.[61] reported 3 epidural catheter-related infections in patients with cutaneous wounds over a 4-year period. All patients were treated with antibiotic therapy; 1 patient underwent transcutaneous drainage of an epidural abscess. However, there were no neurologic deficits. It is difficult to deter-

mine the actual risk of epidural abscess in patients with chronic localized infections who undergo epidural catheter placement because of the small number of patients studied and the rarity of this complication. Therefore, the clinician must maintain vigilance in neurologic monitoring to ensure early recognition and treatment.

Herpes Simplex Virus

Herpes simplex virus type 2 (HSV-2) infection is an incurable, recurrent disease characterized by asymptomatic periods alternating with recrudescence of genital lesions. The primary infection is associated with viremia and can be accompanied by a variety of symptoms, including fever, headache, and rarely aseptic meningitis. In contrast, recurrent or secondary infections present as genital lesions without evidence of viremia. When obstetric patients present for delivery with evidence of active HSV-2 infection, cesarean delivery is recommended to avoid exposing the neonate to the virus during vaginal delivery. Neuraxial block in these patients is controversial because of the theoretical potential of introducing the virus into the central nervous system (CNS). However, there are little data to support these concerns.

Bader et al.[62] reviewed the management of 169 parturients with HSV-2 infections; five of which were primary infections. Although general anesthesia was administered to 59 patients, the remaining 110 patients received spinal or epidural techniques. One patient with primary HSV-2 infection developed transient unilateral leg weakness after bupivacaine spinal anesthesia. The authors concluded that neuraxial block was safe in cases of secondary infection. Additional investigations support these recommendations, although the total number of patients studied is too limited to make a definitive assessment.[63,64] In addition, because the risk of neurologic complications in patients undergoing neuraxial block in the presence of primary infection remains unknown, a conservative approach is recommended.

HSV type 1, the infectious agent of oral herpes, rarely causes genital lesions. However, recurrent HSV-1 infection has been described in parturients receiving intrathecal and epidural opioids.[65] The postnatal association is controversial since other factors, including emotional or physical stress, have been implicated as causes of recurrent HSV-1 infection.

Human Immunodeficiency Virus

The risk of performing neuraxial block in patients infected with human immunodeficiency virus (HIV) is largely undetermined. Approximately 40% of patients with the diagnosis of acquired immunodeficiency syndrome (AIDS) have clinical signs of neuropathy, and 70% to 80% have neuropathic changes present at autopsy. Because the virus infects the CNS early in the disease, it is unlikely that neuraxial block would result in new CNS transmission. However, the neurologic symptoms associated with HIV infection such as aseptic meningitis, headache, and polyneuropathy would be indistinguishable from those related to regional technique. Hughes et al.[66] reported safe administration of neuraxial block to 18 HIV-infected parturients. However, the patients were relatively healthy and in the early stage of their disease. Uncomplicated placement of an epidural blood patch for treatment of postdural puncture headache in 9 HIV-positive patients has also been described.[67] A clear understanding of the association of CNS symptoms with HIV infection is important to interpret postblock (or postblood patch) neurologic findings.

Anesthetic Management of the Infected or Febrile Patient

In summary, several clinical and laboratory studies have suggested an association between dural puncture during bacteremia and meningitis. The data are equivocal, however. The clinical studies are limited to pediatric patients who are historically at high risk for meningitis. Many of the original animal studies used bacterial counts that were far in excess of those noted in humans in early sepsis, making CNS contamination more likely. Despite these conflicting results, it is generally recommended that except in the most extraordinary circumstances, neuraxial block should not be performed in patients with untreated bacteremia.

Patients with evidence of systemic infection may safely undergo spinal anesthesia if antibiotic therapy is initiated before dural puncture and the patient has responded to therapy, such as a decrease in fever. Placement of an indwelling epidural (or intrathecal) catheter in this group of patients remains controversial; patients should be carefully selected and monitored for evidence of epidural infection. Spinal anesthesia may be safely performed in patients at risk for low-grade transient bacteremia after dural puncture. Once again, little information exists concerning the risk of epidural anesthesia in patients suspected of developing an intraoperative transient bacteremia (such as during a urologic procedure). However, short-term epidural catheterization is most likely safe.

All patients with an established local or systemic infection should be considered at risk for developing

infection of the CNS. A delay in diagnosis and treatment of even a few hours significantly worsens neurologic outcome. Bacterial meningitis is a medical emergency. Mortality is approximately 30%, even with antibiotic therapy. Meningitis presents most often with fever, severe headache, altered level of consciousness, and meningismus. The diagnosis is confirmed with a lumbar puncture. Lumbar puncture should not be performed if spinal abscess is suspected, because contamination of the intrathecal space may result. CSF examination in the patient with meningitis reveals leukocytosis, a glucose level of less that 30 mg/dL, and a protein level greater than 150 mg/dL.

The clinical course of epidural abscess progresses from spinal ache and root pain, to weakness (including bowel and bladder symptoms), and eventually paralysis. The initial back pain and radicular symptoms may remain stable for hours to weeks. However, the onset of weakness often progresses to complete paralysis within 24 hours. Although the diagnosis was historically made with myelogram, radiologic examination such as computed tomography scan, or preferably MRI, is currently recommended. A combination of antibiotics and surgical drainage remains the treatment of choice. As with spinal hematoma, neurologic recovery is dependent on the duration of the deficit and the severity of neurologic impairment before treatment.

Neuraxial Block in Patients With Preexisting Neurologic Disorders

Patients with preexisting neurologic disease present a unique challenge to the anesthesiologist. The cause of postoperative deficits is difficult to evaluate, because neural injury may occur as a result of surgical trauma, tourniquet pressure, prolonged labor, improper patient positioning, or anesthetic technique. Progressive neurologic diseases such as multiple sclerosis may coincidentally worsen perioperatively, independent of the anesthetic method. The most conservative and admittedly legal approach is to avoid regional anesthesia in these patients. However, specific patients, including those with significant cardiopulmonary disease, may benefit medically from regional anesthesia and analgesia. The decision to proceed with a regional anesthesia in these patients should be made on a case-by-case basis.

Patients with preexisting neurologic disorders of the CNS, such as multiple sclerosis or amyotrophic lateral sclerosis (ALS), lumbar radiculopathy, and ancient poliomyelitis present potential management dilemmas for anesthesiologists. The presence of preexisting deficits, signifying chronic neural compromise, theoretically places these patients at increased risk for further neurologic injury. It is difficult to define the actual risk of neurologic complications in patients with preexisting neurologic disorders who receive regional anesthesia; no controlled studies have been performed, and accounts of complications have appeared in the literature as individual case reports. The decision to use regional anesthesia in these patients is determined on a case-by-case basis and involves understanding the pathophysiology of neurologic disorders, the mechanisms of neural injury associated with regional anesthesia, and the overall incidence of neurologic complications after regional techniques. Although laboratory studies have identified multiple risk factors for the development of neurologic injury after regional anesthesia, clinical studies are lacking. Even less information is available for the variables affecting neurologic damage in patients with preexisting neurologic disease. Several neurologic conditions warrant a more comprehensive discussion.

Multiple Sclerosis

Multiple sclerosis is a degenerative disease of the central nervous system, characterized by multiple sites of demyelination in the brain and spinal cord. The peripheral nerves are not involved. The course of the disease consists of exacerbations and remissions of symptoms, and the unpredictability in the patient's changing neurologic status must be appreciated when selecting an anesthetic technique. Stress, surgery, and fatigue have been implicated in the exacerbation of multiple sclerosis. Epidural and, more often, spinal anesthesia have been associated with relapse of multiple sclerosis, although the evidence is not strong.[68] The mechanism by which spinal anesthesia may exacerbate multiple sclerosis is unknown, but some speculate it may be direct local anesthetic toxicity. Epidural anesthesia has been recommended over spinal anesthesia because the concentration of local anesthetic in the white matter of the spinal cord is one fourth the level after epidural administration.[69] A dilute solution of local anesthetic with spinal or epidural anesthesia is also advised. Because multiple sclerosis is a disorder of the CNS, peripheral nerve blocks do not affect neurologic function and are considered appropriate anesthetic techniques.

Diabetes Mellitus

A substantial proportion of diabetic patients have clinical symptoms of a neuropathy. However, a subclinical neuropathy may be present before the onset of pain, paresthesia, or sensory loss and may remain undetected without electrophysiologic testing showing typical slowing of nerve conduction

velocity. The presence of underlying nerve dysfunction suggests that patients with diabetes may have a decreased requirement for local anesthetic. The diabetes-associated microangiopathy of nerve blood vessels decreases the rate of absorption, resulting in prolonged exposure to local anesthetic solutions. The combination of these 2 mechanisms may theoretically cause nerve injury with an otherwise safe dose of local anesthetic in diabetic patients.

In a study examining the effect of local anesthetics on nerve conduction block and injury in diabetic rats, Kalichman and Calcutt[19] reported that the local anesthetic requirement is decreased, and the risk of local anesthetic-induced nerve injury is increased in diabetes. These findings suggest that diabetic patients may require less local anesthetic to produce anesthesia and that a reduction in dose may be necessary to reduce the risk of neural injury by doses considered safe in nondiabetic patients. However, confirmatory human studies are lacking.

In summary, patients with preexisting neurologic disorders such as multiple sclerosis, polio, or ALS may develop new neurologic deficits perioperatively. It is often difficult to differentiate between surgical or anesthetic causes.[2] The medicolegal issue, however, remains, and if a regional anesthetic is indicated (or requested), the patient's preoperative neurologic examination should be formally documented, and the patient must be made aware of the possible progression of the underlying disease process. Although stable preexisting neurologic conditions such as an inactive lumbosacral radiculopathy or hemiparesis associated with an ancient cerebrovascular accident are not contraindications to neuraxial anesthesia, the underlying etiology of such neurologic deficits requires careful evaluation.

Performance of Neuraxial Blocks in Patients Under Anesthesia

The performance of regional blocks on anesthetized patients theoretically increases the risk of perioperative neurologic complications, because these patients are unable to respond to the pain associated with needle- or catheter-induced paresthesias or intraneuronal injections. However, there are few data to support these concerns. Cases are typically reported individually; no randomized study or large review has been performed to date.[70,71] There may also be medicolegal issues. The actual risk of neurologic complications in patients undergoing regional techniques while anesthetized or heavily sedated has not been formally evaluated.

Regional Anesthesia in Anesthetized Children

Most children who undergo regional anesthetic techniques are either heavily sedated or under general anesthesia at the time of block.[72-74] Although this is considered "acceptable" anesthetic management, it could also be argued that except in cases where there is a documented improvement in perioperative outcome the use of this technique should be minimized. Nevertheless, studies involving regional anesthesia in the pediatric population are perhaps the best source of evaluating the risk of neurologic complications in anesthetized patients.

The largest prospective study evaluating the morbidity of regional anesthesia in children was performed by Giaufre et al.[75] There were 24,409 regional blocks; 89% were performed under general anesthesia and 6% were performed in the presence of sedation. Approximately 50% of the blocks were performed in patients between 3 and 12 years of age. Neuraxial blocks—the majority of which were caudal blocks—accounted for 15,013 (>60%) of all regional anesthetics. However, there were 506 spinals (75% of which were performed in premature infants), and 135 thoracic epidural anesthetics. Catheters were placed in only 1,026 of 2,396 (43%) epidural patients. All 23 complications occurred after neuraxial block, for an overall incidence of 1.5 per 1,000 cases. None resulted in long-term sequelae or medicolegal action.

This study is significant for several reasons. First, it documents the relative safety of regional anesthesia in children. Although it is possible that not all neurologic complications were discovered, it is doubtful that major morbidity went unreported. The etiology of complications is also important. Half of the 23 reported complications (4 total spinals, 6 intravascular injections, and 2 transient paresthesias) may have been influenced by the patient's alertness during the performance of the neuraxial block. These data also support meticulous regional anesthetic technique including careful calculation of total local anesthetic dose, the use of a test dose, intermittent injection/aspiration, and continuous electrocardiographic monitoring.

Regional Anesthesia in Anesthetized Adults

To date, there are no prospective studies evaluating the performance of regional techniques in anesthetized adults. However, several retrospective reviews have suggested that under certain circumstances, neuraxial block may be safe. Abel et al.[76] reviewed the records of 4,392 consecutive epidural catheters placed in anesthetized adult patients undergoing upper abdominal or thoracic surgery. Epidural catheters were placed either immedi-

ately after induction and tracheal intubation or on completion of the surgical procedure, prior to emergence. Epidural catheterization occurred at the lumbar level in all but 4 patients who underwent thoracic epidural placement. Nearly all infusions (98.4%) contained an opioid only. There were no documented neurologic complications including spinal hematoma, epidural abscess or catheter site infections, or radicular symptoms. In 1 patient, the epidural catheter broke during removal and a portion was retained; no long-term sequelae were noted. In spite of the lack of neurologic complications among these patients, the possibility of a serious neurologic event may be as high as 0.08% (95% confidence interval).

Neurosurgical patients frequently undergo needle and catheter placement (without administration of local anesthetics) under general anesthesia. Grady et al.[77] assessed the frequency of neurologic complications in 478 patients undergoing transphenoidal surgery in conjunction with intraoperative spinal drainage. Malleable needles or spinal drainage catheters were placed after tracheal intubation. Although the drains were used intraoperatively for air injection or CSF removal in 54% and 41% of patients, respectively, no potentially neurotoxic agent was administered. There were no neurologic deficits attributable to spinal drainage (95% confidence interval 0.0% to 0.8%). Although it is possible that minor neurologic sequelae were missed because of the retrospective nature of these two reviews, it is doubtful that any significant complications were undiscovered.

Although these results are reassuring, they must be carefully interpreted. The anesthesiologist unskilled in regional anesthesia should not attempt to learn new techniques with this patient population. In addition, the use of a nerve stimulator does not replace the patient's ability to respond to the pain of needle trauma or intraneuronal injection. A case of permanent spinal cord injury in a patient who underwent interscalene block using a nerve stimulator technique while under general anesthesia has been reported.[3] Although the safety of regional blocks performed on anesthetized pediatric patients is well documented, the decision to perform a regional anesthetic on a heavily sedated or anesthetized patient (adult *or* pediatric) should not be made indiscriminately.

In conclusion, although rare, major complications after neuraxial techniques can be devastating to the patient and the anesthesiologist. Prevention and management begin during the preoperative visit with a careful evaluation of the patient's medical history and appropriate preoperative discussion of the risks and benefits of the available anesthetic techniques. Alternative anesthetic techniques such as peripheral regional techniques or general anesthesia should be considered for patients at increased risk for neurologic complications following neuraxial block. The decision to perform a regional anesthetic technique on an anesthetized patient must be made with care because these patients are unable to report pain on needle placement or injection of local anesthetic. Efforts should also be made to decrease neural injury in the operating room through careful patient positioning. Postoperatively, patients must be followed closely to detect potentially treatable sources of neurologic injury, including expanding spinal hematoma or epidural abscess, constrictive dressings, improperly applied casts, and increased pressure on neurologically vulnerable sites. New neurologic deficits should be evaluated promptly by a neurologist or neurosurgeon to document formally the patient's evolving neurologic status, arrange further testing or intervention, and provide long-term follow-up.

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