This chapter contains a comprehensive, albeit concise, discussion of the complications mentioned in the three preceding chapters pertaining to various regional anesthetic techniques that can occur as a direct or indirect effect of carrying out the procedure and/or managing the patient. Complications that are associated with general anesthesia are considered in Chapter 20. The complications considered here are based on the primary pathophysiology involved. For example, because arterial hypotension can occur with lumbar epidural, caudal epidural or subarachnoid block, it is discussed not in relation to the technique, but in relation to the primary pathophysiologic process.

The material is presented in four major sections: 1) cardiovascular complications including arterial hypotension and cardiac arrest; 2) systemic toxic reactions to the local anesthetic that involve primarily dysfunction of the cardiovascular and neurologic systems, or other systemic reactions not related to the local anesthetic; 3) neurologic complications; and 4) a heterogeneous grouping, which includes complications that do not fit in any of the other categories and that may have deleterious effects on several organs/functions. In discussing the same complication caused by different techniques, we point out differences and similarities in the characteristics of the complication. Portions of this chapter have been taken from the first edition of this book (1) and from a chapter written by Chadwick and Ross (2).

Cardiovascular dysfunction, but specifically arterial hypotension, has been and continues to be the most frequent complication associated with subarachnoid block, lumbar epidural block, and caudal epidural block administered to parturients. In the past, death consequent to profound hypotension that ended in cardiac arrest was not an infrequent cause of maternal mortality (1,2) and a major contributing factor to perinatal morbidity and perhaps mortality. In the first edition of this book, Bonica presented detailed analysis of data published between 1940 and 1965 that revealed that among the causes of maternal mortality due to anesthesia, cardiovascular complications were the most frequent cause of death associated with regional anesthesia (1). The analysis revealed that cardiovascular complications accounted for about 30% of the maternal deaths associated with anesthesia. These deaths caused by cardiovascular complications were only second to deaths caused by aspiration of gastric contents during the course of general anesthesia.

Fortunately, during the past 25 to 30 years, advances have been made in the fields of obstetrics, perinatology, and anesthesiology, and these have converged to greatly improve obstetric anesthesia services and to drastically reduce maternal and perinatal mortality. We have acquired a great amount of new information about the physiology and pathophysiology of the mother, fetus and newborn, and placental function. These have been followed by improvement in the prevention and treatment of complicating disorders. Moreover, in the United States there has been a significant increase in the number of physicians who are currently devoting their time and effort to obstetric anesthesia and many of who
have continually modified and improved the various techniques of regional anesthesia so that they can be applied safely. Still another very important factor that has helped the care of parturients subjected to regional anesthesia has been the large number of studies on human volunteers and low-risk obstetric and surgical patients. The results of these studies have greatly helped to define the action of various techniques of lumbar epidural, caudal epidural, and subarachnoid block on the mother, fetus and newborn, and on the forces of labor. These have led to the development and application of prophylactic measures to avoid or minimize complications. We will briefly review recently published data relevant to each issue.[/]

[h3]ARTERIAL HYPOTENSION[/]

[h4]Basic Considerations[/]

[p]In gravidae and parturients who are otherwise "normal" and do not have complicating disorders, arterial hypotension is defined as a 20 to 30% reduction in baseline systolic pressure or a reduction of mean arterial pressure below 100 mm Hg. Because data on the frequency and magnitude of arterial hypotension consequent to the older techniques of subarachnoid block and epidural block and its incidence with the modifications currently practiced are presented in Chapters 13, 14 and 15, they are only briefly mentioned here. We will focus much of the discussion on the pathophysiologic factors that underlie its occurrence.[/]

[p]Until the early 1960s, it was believed and taught that the degree of arterial hypotension consequent to neuraxial blocks was directly related to the number of vasomotor segments interrupted, a concept that Bonica discussed in the first edition of this book (1). Although he mentioned or briefly discussed other causes that contribute to hypotension, the extent of the vasomotor block was considered the most influential factor. However, data derived from the aforementioned clinical observations and controlled studies published subsequently, suggested that the condition of the patient and the presence of complicating disorders are the most important etiologic factors that determine the frequency and degree of arterial hypotension. These include: 1) degree of sympathetic vasomotor tone before the block (especially if a high tone is present, provoked by anxiety and apprehension or by injury or disease); 2) blood volume and nutrition of the patient; 3) presence or absence of cardiovascular disease; and 4) efficiency of circulatory homeostatic mechanisms that may be impaired by depressant drugs or by pathophysiologic factors. In otherwise normal parturients, the degree of aortocaval compression by the gravid uterus is by far the most important factor that determines the degree of hypotension consequent to subarachnoid or extradural blockade. In addition to these and the extent of sympathetic blockade produced, other factors that may play a role in determining the magnitude of arterial hypotension include the total amount of local anesthetic used and whether or not epinephrine is included in the solution injected.[/]

[p]To duly emphasize the relevance of all of these findings from recent studies toward the prevention and treatment of arterial hypotension in obstetric patients, we first discuss very briefly the physiology of circulatory homeostasis and then briefly summarize some of the data derived from controlled studies.[/]

[h4]Physiology of Circulatory Homeostasis[/]
It has long been known that circulatory homeostasis is maintained primarily by intrinsic and extrinsic mechanisms and the volume of blood, all working in concert and with exquisite interaction, integration, and coordination, which continuously detect and compensate for any deviation in the blood pressure (3-5). The intrinsic mechanisms include the vasomotor tone of the blood vessels, the Frank-Starling mechanisms of the heart, and the blood volume, which frequently shifts from one vascular bed to another in response to the needs of different body tissues. The extrinsic mechanisms are comprised of the vagal parasympathetic function, which when stimulated decreases chronotropic and inotropic action of the heart, and the sympathetic system, which when stimulated increases inotropic and chronotropic activity and constricts blood vessels. Normally, tonic sympathetic outflow partly controls the tone of vessels of both the arterial and venous system. Blockade of sympathetic outflow results in dilatation of arterial resistance vessels and the venous capacitance vessels. Vasoconstrictive tone of blood vessels is composed of an extrinsic part provided by continuous sympathetic vasoconstrictor impulses and an intrinsic vasomotor tone. Sympathetic blockade eliminates the former, but not the latter, i.e., during sympathetic blockade associated with subarachnoid, epidural or peripheral nerve block, decrease in vascular resistance is rarely maximal because the intrinsic vasomotor tone is autonomously maintained. Intrinsic vasomotor tone can be decreased or eliminated by drugs that directly depress the smooth muscle of the vessels. Factors that decrease or eliminate intrinsic vasomotor tone include histamine, halothane, thiopental, hypoxemia, and severe acidosis, among others. The clinical implication of these effects is that administration of such drugs or development of asphyxia will increase the degree of hypotension in a patient already under the influence of sympathetic blockade.[]

The exquisitely sensitive extrinsic neurogenic influences involve reflexes that are activated by stimulation of baroreceptors and chemoreceptors in the carotid sinus and aortic arch, and by atrial and ventricular stretch receptors and the receptors in the low pressure vessels of the thorax as depicted in Figure 16-1[fig16-1]. The afferent pathways are contained in the glossopharyngeal and vagus nerves, which convey afferent impulses to the vasomotor and cardiac centers where they are integrated and interpreted, and thence provoke efferent impulses that reach the target organs--the heart and blood vessels--via the vagus and sympathetic efferent fibers. The vagi act as the parasympathetic mediators to the cardiovascular system and carry impulses to the sinoatrial and the atroventricular nodes and the atrial myocardium, while the sympathetic nerves innervate all of the tissues of the cardiovascular system. In healthy individuals with normal blood volume, these two fundamental regulatory mechanisms--the intrinsic and extrinsic controls--continue to be operative, acting in concert and in exquisite coordination to maintain circulatory homeostasis. Impairment of one factor results in increase in the effect of the other. Thus, if the extrinsic sympathetic nervous system control is decreased, the Frank-Starling mechanism assumes a more prominent role. Conversely, in patients with impaired myocardial function, there is increased sympathetic activity and concomitant decrease in parasympathetic influence.[/]

Response to Neural Blockade in Healthy Humans[/]

In this section we briefly review data derived from the aforementioned controlled studies in human volunteers and low-risk surgical and obstetric patients on the cardiovascular effects of: 1) the different levels of neural blockade; 2) rapidity with which high blockade is produced; 3) effects of epinephrine included in the local anesthetic solution; 4) influence of the local anesthetics on the heart and blood vessels; and 5) influence of hypovolemia and of agents and conditions that impair circulatory
homeostatic mechanisms. The data cited were published by many workers including, Greene (3), Bromage (6,7), Defalque (8), Shimosato and Etsten (9), Otton and colleagues (10,11), and by Bonica and associates, who, during the course of a decade and a half, carried out 43 different studies involving 70020 human subjects (12-27). These subjects were healthy, unmedicated volunteers who were used to determine the influence of vasomotor block. In addition, the studies included patients undergoing surgical operations, and gravidae who underwent vaginal delivery or cesarean section (20-22,25,26). Here we cite only those relevant to this present subject (12-34).

Effects of Levels of Neural Blockade

1) In several studies in which cutaneous analgesia to T10 was achieved with either subarachnoid or epidural block in healthy unmedicated volunteers, no significant changes in any of the hemodynamic parameters were found (13,14,19).

2) Comparison of the effects of T4-5 continuous epidural analgesia (CEA) with T4-5 subarachnoid block (SAB) carried out in the same group at different times showed that SAB produced a much greater degree of hypotension than did epidural analgesia (12,13).

3) Studies were done to determine the hemodynamic effects of high epidural and high subarachnoid block achieved by injecting the drug in small, incremental doses to produce a step-wise analgesia to T10, T8, T6, T4. Figure 16-2 shows that with SAB below T6 there were minimal, clinically insignificant changes in mean arterial pressure (MAP), cardiac output (CO), and total peripheral resistance (TPR), but block above T1 was associated with a significant decrease in CO and TPR resulting in a 20% decrease in MAP. Figure 16-3 shows the results obtained with CEA, achieved with 2% lidocaine injected in a similar step-wise fashion (21).

The much greater degree of hypotension seen with a single dose of the local anesthetic, than which occurred with several small, incremental doses, was attributable to the fact that the onset of sympathetic blockade was much faster with a single dose than with several small, incremental doses. These data strongly suggest that, ideally, epidural anesthesia for cesarean section should be achieved by giving incremental doses over a period of 15 to 20 minutes or more.

4) Another important issue relevant to obstetric anesthesia brought out by a study of progressively higher levels of continuous epidural blockade was the cardiac stimulating effect of lidocaine. Figure 16-3 shows that blockade to the T4-T5 segments produced only small changes in the various hemodynamic parameters. Even more important is the fact that with analgesia block at T2-T3 level, which was achieved after the fourth or fifth injection entailing the use of a total of 1000 to 1200 mg of lidocaine given over a 4-hour period (17) and resulting in arterial blood lidocaine levels ranging between 4 and 6 [micron]g/ml, there was a significant increase in CO due solely to increase in cardiac rate. On the basis of these data and the experimental results reported by Kao and Jalar (28) and Jorfeldt and associates (29), we speculated that this chronotropic effect represented a predominance of lidocaine-induced stimulation of cardiovascular centers in the brain stem with consequent increase in sympathetic nervous system stimulation and some direct peripheral vasoconstriction. In a subsequent study, this hypothesis was confirmed (16) in subjects who were given intravenous infusions of lidocaine that produced a similar increase in CO and cardiac rate, and this was eliminated by producing a
segmental SAB with 2 to 3 mg tetracaine injected at T2 interspace to produce sympathetic blockade of the heart.

[p]Because blood levels of 4 [micron]g/ml of lidocaine usually develop following single epidural injection of 400 mg or following several injections of 200 to 300 mg of lidocaine (27), these findings have obvious clinical implications in obstetric patients who require continuous epidural anesthesia for prolonged labor for which repeated injections are usually given hourly. Because adult humans require considerably longer than 1 hour to metabolize and eliminate lidocaine, the drug will accumulate to significant levels in blood plasma and body tissues (30).

[h4]Effects of Epinephrine[/h4]

[p]Many studies have also shown that epidural block achieved with lidocaine containing epinephrine in total doses ranging from 40 to 250 [micron]g produces a predominant beta-adrenergic action consisting of increases in heart rate (HR), stroke volume (SV) and CO and a significant decrease in TPR resulting in a decrease in MAP (2,13,18). Apparently, absorption of these amounts of epinephrine is so slow as to produce almost a pure beta-adrenergic action that affects the peripheral portion of the circulation to a slightly greater degree and slightly longer time than its action on the heart.]

[p]The remarkably small alterations usually seen in normovolemic unmedicated subjects given high epidural or subarachnoid block are in contrast with significant cardiovascular depression seen among surgical patients, particularly those given high block for upper abdominal surgery. The most important factors contributing to cardiovascular depression seen in these patients include: 1) high degree of sympathetic tone before the block, provoked by anxiety and apprehension, injury, or by disease; 2) acute or chronic hypovolemia from any cause; 3) cardiovascular disease; 4) impairment of homeostatic circulatory mechanisms; and 5) mechanical obstruction of venous return to the heart.

[h4]Effects of Acute Blood Loss[/h4]

[p]Studies were carried out to determine the influence of acute blood loss in healthy human volunteer subjects given: 1) high (T4-5) subarachnoid block achieved with 40 to 50 mg of lidocaine and dextrose; 2) high epidural block achieved with 18 to 22 ml of 2% lidocaine containing 1:200,000 epinephrine; and 3) high epidural achieved with 2% lidocaine alone. The general protocol included usual rest periods and measurements of all hemodynamic and respiratory parameters, before and during the duration of the block in the normovolemic state. This was followed by another rest period and a second group of control measurements, after which 10 ml/kg of whole blood was withdrawn within a fixed period of 15 to 20 minutes which, according to the studies of Moore and associates (31), represents 13% of the total blood volume and simulates moderate hemorrhage. Measurements were repeated at 10 and 30 minutes after blood withdrawal, followed by a 10-minute rest period, and a second injection of the same amount of local anesthetic. Measurements were repeated when T5 block was established and every 30 minutes thereafter until all signs of blockade disappeared. After completion of the study, the blood was reinfused into the subject.

[p]Figure 16-4 summarizes the results obtained in one study in which the effects of high epidural block were measured in the normovolemic state (not shown) and after acute blood loss (19). Part A shows the response to 20T5 epidural block achieved with 2% lidocaine and 1:200,000 epinephrine in
1520 subjects after they had been made hypovolemic. Apparently, the epinephrine produced a positive inotropic and chronotropic effect increasing CO to about 18%, which offset the 30% decrease in TPR, resulting in a 22% decrease in MAP. It had been planned that the study would be repeated in 15 subjects using similar volumes of 2% lidocaine without epinephrine. However, because five of the first seven subjects had a precipitous fall in MAP to profound levels and 2 had an asystole lasting about 10 seconds, the study was terminated (Figure 16-4B). The five subjects who developed severe cardiovascular depression were immediately given 15 to 25 mg ephedrine via the superior vena cava catheter to restore arterial blood pressure to near normal levels.

In the latter group, MAP decreased to a mean of 41% of control, central venous pressure (CVP) from 2 to -0.7 cm H₂O, and HR to 70% of control (Figure 16-4B). The difference between the results of the two epidural solutions is the fact that the epinephrine-containing lidocaine had some beneficial cardiac-stimulating effect to prevent the profound cardiovascular depression seen with lidocaine alone. This profound depression was probably due to the rapid absorption of lidocaine producing arterial blood levels in excess of 11 20 μg/ml (27), which together with the metabolic acidosis consequent to the hypotension produced severe myocardial depression. A similar study with high subarachnoid block was carried out before and after acute blood loss. In this group, MAP was reduced 30% below control value; cardiac output was reduced 15%; stroke volume had decreased nearly 22%, and central venous pressure was 66% below the control values.

It is apparent that loss of moderate quantities of blood in young healthy unmedicated persons significantly increased the deleterious effects of high SAB or epidural anesthesia. The clinical implications of these studies are obvious. High subarachnoid or epidural block should be avoided in parturients who have moderate to severe hypovolemia. In very rare and special circumstances in which the patient's conditions contraindicate general anesthesia or present even greater risks, subarachnoid or epidural block can be used provided a T4-T5 analgesia can be used, but only after the blood volume is increased with whole blood or colloid solutions and other prophylactic measures are taken, as mentioned later. Moreover, the analgesia should be achieved with several incremental doses, and the parturient's hemodynamics should be monitored continually with techniques that provide second-to-second information.

Effects of Pregnancy

Fall in arterial blood pressure following subarachnoid or epidural block to a specific level is greater and more rapid in pregnant than in nonpregnant women. This has been demonstrated in a number of studies during the past 3 decades. One of the first studies was carried out by Assali and Prystowsky (32), who noted a "negligible fall" in arterial pressure in normotensive, nonpregnant women during high subarachnoid block, compared to normotensive term pregnant women. When anesthetic block was repeated 35 to 48 hours after delivery, the average fall in systolic pressure was similar to that of nonpregnant level (Figure 16-5). In otherwise healthy gravidae, the primary reason for the greater degree of hypotension is decreased venous return to the heart due to occlusion of the inferior vena cava and other large veins by the gravid uterus. The effect of caval compression by the uterus was clearly demonstrated in half a dozen studies carried out by Ueland, Hansen, and Bonica and associates at The University of Washington.

In each of the studies pertaining to obstetrics, term gravidae were used and cardiovascular and respiratory parameters measured before and after induction of
the block with the patient in the supine position, and then repeated in the lateral position before surgery was initiated. Because studies were carried out to evaluate the influence of these various types of anesthesia, the usual prophylactic measures of a given infusion of fluids and/or administration of vasopressors were omitted. The measurements were then repeated during the operation in the supine position: 1) at the moment the abdomen was opened; 2) immediately after delivery of the infant; and 3) at 10 minutes and 1 hour postpartum. Measurements of blood volume and arterial hematocrit were obtained before delivery and at 10 minutes and 1 hour postpartum, and on postpartum days 1, 3, and 5. Table 16-1 contains a summary of the maximum changes in maternal hemodynamics, noted with three types of regional anesthesia and with balanced general anesthesia.

In the first study, subarachnoid block achieved with 7 to 10 mg tetracaine and 200 μg epinephrine was used (20). The levels of analgesia were below T5 in three of the parturients. Moreover, these patients had lateral uterine displacement, but no vasopressors for the treatment of hypotension to assess the magnitude of the hemodynamic changes. In another 14 patients who underwent cesarean section with SAB, hypotension was treated promptly with vasopressors. Figure 16-6, developed from data of the first group, shows the significant difference in various cardiovascular parameters when the patient was supine and when the patient was in the lateral position. This illustration, which shows mean values, clearly demonstrates that the compression of the inferior vena cava was the sole etiologic factor responsible for the cardiovascular changes. Thus, it is noted that merely opening the abdomen resulted in some restoration of MAP toward normal levels, a result of improved SV and HR, and, consequently, CO and MAP. This restoration effect probably resulted from a decrease of intra-abdominal pressure and in turn decrease of the pressure exerted on the inferior vena cava and consequent increase in venous return. This beneficial effect was further enhanced after delivery of the infant, when these various parameters return to normal or slightly above normal. Because the level of sympathetic blockade at the latter two points and at the point marked postpartum remained at the same level as before the delivery of the infant, the only conclusion that can be considered is that the compression of the veins was the primary etiologic factor in producing hypotension. That the level of vasomotor block played little or no role in these changes is suggested by the fact that in this study group and in the other 14 patients who had cesarean section with subarachnoid block, patients with T8 or T9 block before the opening of the abdomen had the same degree of cardiovascular depression as those who had T4 or T5 block. The authors concluded that there was a lack of correlation between the level and dose of anesthesia and severity of maternal cardiovascular depression. Measurement of blood gases and pH revealed that some of the patients hyperventilated with a consequent increase in PaO2, decrease in PaCO2, and increase in pH. In this group, the hypotension did not appear to have any consistent deleterious effects on newborn infants whose blood gases were within normal limits, and the Apgar rating ranged from 6 to 9, with a mean score of 8 for the group. It was also noted that the administration of oxytocin injected intravenously after the delivery produced a transient (3 to 4 minutes) decrease in systolic and diastolic pressure and increase in HR. The mean blood volume decreased 16% (1004 ml), with a range of 400 to 1650 ml.

In a second study, the group evaluated the effects of a continuous epidural block achieved with 122D16 ml of 2% mepivacaine (Carbocaine) without epinephrine (21). In several patients, the level of anesthesia was inadequate and required supplementation with 50% N2O by mask before delivery. In two patients, increments of 3 mg of morphine sulfate were given intravenously for relief of discomfort encountered during closure of the uterine incision. This
study showed the same trend in cardiovascular and respiratory parameters as with subarachnoid block except that the degree of hypotension was significantly less. Table 16-1 shows that the block before the operation caused a decrease of about 6% in CO and 11% in MAP. Upon opening the abdomen, CO increased 12%, which together with an 18% decrease in TPR consequent to the vasomotor block resulted in an 11% decrease in MAP. Following delivery of the infant, CO increased 25%, which together with a 26% decrease in TPR resulted in an 11% decrease in MAP. Subsequently, these parameters remained the same, indicating stabilization of the hemodynamics. None of the patients required vasopressors as had been the case with subarachnoid block. It is apparent that continuous epidural block without epinephrine caused less hemodynamic alteration than did subarachnoid block. Maternal and fetal blood gases and Apgar scores were within normal limits, and the amount of blood loss was similar to the group that received subarachnoid block.

A third study was carried out with epidural anesthesia achieved with 12 to 16 ml of mepivacaine with 1:200,000 epinephrine injected as a single bolus (22). To the surprise of the investigators, the parturients manifested a decrease of 16% in SV, which resulted in a 17% decrease in CO. These, together with a 16% decrease in TPR, resulted in a 37% decrease in MAP, which was somewhat smaller than the effects with subarachnoid block but significantly greater than the effects of epidural achieved with plain mepivacaine. Because of the rapid onset of hypotension, 10 of the 12 parturients required therapy soon after the onset of block, consisting of left uterine displacement, rapid intravenous infusion, pressure booted inflation of the legs, and intravenous injection of ephedrine. The reason for the greater alterations in this group of patients as compared to the group receiving epidural with mepivacaine alone was primarily due to a decrease in stroke volume and a much greater decrease in TPR from the epinephrine-induced vasodilation. Following opening of the abdomen, SV and CO were restored to preanesthetic levels and were due to lessening of the compression of the inferior vena cava and the consequent decrease in venous return. The effects on peripheral resistance remained until 1 hour after the operation. Notwithstanding the significant differences between the two groups, maternal and fetal blood gases and pH and Apgar scores were within normal limits and were very similar to those noted in the group receiving mepivacaine alone.

To recapitulate, from these and other data it is obvious that the primary reason for the hypotension with subarachnoid block and epidural block achieved with a local anesthetic without epinephrine is due to compression of the inferior vena cava by the gravid uterus. The addition of epinephrine may exaggerate the hypotension by additional peripheral vasodilation. The significant increase in stroke volume and cardiac output immediately after delivery of the infant and 10 minutes later is primarily due to removal of the compression on the inferior vena cava and extrusion of about 500 ml of blood from the contracting uterus into the central blood volume. Ueland and associates (20-22) suggested that, together with the removal of the vena cava compression, the blood that had pooled into the lower limbs during the compression increased the venous return to the heart of about 1000 ml. This is reflected by the significant increase in SV and CO after delivery of the infant, and it was just sufficient to offset the decrease in TPR caused by the vasomotor block resulting in a parallel increase in blood pressure.

Supine Hypotensive Syndrome

At this point mention is made of the "supine hypotension syndrome" discussed in detail in Chapter 2. This term, first used in 1953 by Howard and associates
applies to 10 to 15% of gravidae who develop hypotension in the supine position, and is due to impeded venous blood return from the pelvis and lower limbs to the heart. The other 85 to 90% maintain their blood pressure by compensatory vasoconstriction and an increase in HR, but despite these compensations, most gravidae have a decrease in CO (34,35). Moreover, because there is concomitant compression of the lower aorta, blood pressure is decreased below the obstruction, with consequent reduction of perfusion to the placenta and lower limbs (36). This is reflected by the fact that maintaining parturients in the supine position during labor for even a short period is associated with a progressive decrease in fetal pH (37). As noted in these and other studies, having the gravida on her side relieves more (but not all!) of the compression resulting in a 35 to 40% increase of SV and CO and consequent restoration of blood pressure toward normal (see Figures 2-28 and 2-30 from Chapter 2).

Other factors that aggravate the degree of hypotension in a parturient receiving subarachnoid or epidural block include: 1) hypertension; 2) hypovolemia; 3) severe anemia; 4) severe electrolyte imbalance or acidosis; 5) depression or elimination of intrinsic vasomotor tone; 6) depression of catecholamines from prolonged antihypertensive therapy; and 7) adrenocortical depression from prolonged cortisone administration.

In patients with hypovolemia, peripheral vasodilation results in a greater proportion of the blood being pooled at the periphery than is the case in normal individuals, and, consequently, there is a disproportionately greater reduction in venous return to the heart. For example, in a patient with a normal blood volume of 5 liters, the volume of blood in the legs during spinal blockade is approximately 800 to 1000 ml, or about 16 to 20% of the total blood volume (38). In a patient with a blood volume of only 320 liters, the same area of vasodilation may contain 25 to 30% of the circulating blood volume. Many patients with chronic hypovolemia are able to compensate sufficiently to maintain normal blood pressure, but when spinal block is given, even if it is limited to low spinal levels, it may eliminate enough vasomotor segments to disturb the delicate balance that exists, and the patient develops disproportionately severe hypotension.

Depression of intrinsic vasomotor tone may also play an important role. Normally, dilation of the arteries, arterioles, and metarterioles that follows sympathetic interruption is rarely maximum because of a residual intrinsic tone inherent in all smooth muscle, including that of the arterial tree. The degree of effectiveness of this residual intrinsic tone varies from organ to organ, being most effective in cerebral, cardiac, and renal vessels, less so in splanchnic vessels, still less in vessels of striated muscle, and least effective in skin vessels. This intrinsic tone is diminished or even eliminated by hypercarbia and depressant drugs due to direct effects on the smooth muscle of the vessels.

Patients with pregnancy induced hypertension (PIH) are at particular risk of becoming hypotensive with regional anesthesia. Intravascular volume, which may be less than 80% of normal pregnant values (39), predisposes these patients to significant hypotension with the onset of even midthoracic sympathetic block. The risk of fetal distress is further compounded by the fact that these patients often have abnormal placental vasculature and uteroplacental insufficiency. Any intervention that may lower maternal blood pressure, such as antihypertensive therapy or regional block, must be initiated in a slow, controlled fashion with close attention to intravascular volume status (40). Fetal heart rate monitoring, when available, should be used by the anesthesiologist in...
conjunction with more routine monitors to gauge the effects of anesthetic intervention.

**Effects of Hypotension on the Mother**

**Cardiac Effects**

Although it is widely believed that bradycardia is often seen in association with spinal hypotension, this was never seen in any of the studies carried out by Ueland and associates (20-22). It occurred in a group of healthy human volunteers who developed severe hypotension, bradycardia, and eventually asystole in two instances (19). Usually, this slowing of the heart can be attributed to paralysis of the cardiac accelerator fibers with high segmental block (T1-T4). However, bradycardia can be seen with spinal hypotension in the absence of total sympathetic blockade. A number of studies indicate that decreased venous return to the heart causes a rapid decrease in ventricular volume and provokes the Bezold-Jarish reflex characterized by vagal predominance, which may be even more important in causing bradycardia with arterial hypotension. In some patients, severe hypotension will produce medullary ischemia with consequent depression of respiration that results in hypercapnea, which further aggravates hypotension by its vasodilating effect. Bradycardia can usually be reversed by giving atropine and oxygen. It is important to emphasize that if hypotension and bradycardia are not quickly diagnosed and treated, they can rapidly progress to cardiac arrest in otherwise normal patients having spinal anesthesia (41-44). In many reports, the subjects had anesthesia to T4 or above and very likely developed total sympathetic blockade.

**Coronary Blood Flow (CF)**

Coronary blood flow is decreased during spinal hypotension. However, the ability of the coronary circulation to autoregulate combined with the reduced metabolic demand on the heart during spinal hypotension results in the heart being able to tolerate considerable hypotension without developing myocardial ischemia (45-47). At some poorly defined critical level of hypotension, myocardial ischemia will begin to occur. The degree of hypotension that can be tolerated will be less in patients with coronary artery disease, ventricular hypertrophy, or in patients whose heart is required to perform a greater amount of work, e.g., women in active labor. Recently Palmer, et al (48) reported electrocardiographic (ECG) changes characteristic of myocardial ischemia in 35 out of 93 healthy parturients undergoing cesarean section under regional anesthesia. Although it is not clear if these ECG changes were due to myocardial ischemia, the authors postulated that ventricular distention due to rapid fluid administration combined with decreased diastolic blood pressure might lead to myocardial ischemia in this setting.

**Central Nervous System Effects**

Cerebral blood flow is governed largely by mean arterial blood pressure and local metabolic factors. A decrease in blood pressure is followed by compensatory cerebral vasodilation resulting in a stable level of blood flow. However, at some critical degree of hypotension the cerebral vasculature will be unable to further compensate; any additional fall in blood pressure will result in decreased cerebral blood flow and eventually signs and symptoms of cerebral ischemia. In healthy normotensive men, cerebral ischemia will occur when mean arterial pressure falls to 35 to 40 mm Hg (3,49). Because of considerable individual variation it is best to assume that the critical mean arterial...
pressure is about 55 mm Hg in healthy patients and considerably higher in those
with chronic hypertension, PIH, or other vascular disease (3). One of the most
serious effects of hypotension on the central nervous system is medullary
ischemia, which can cause autonomic instability and depression of respiratory
centers. If not diagnosed and treated quickly, the result can be respiratory
arrest and cardiovascular collapse. The most common cause of central nervous
system (CNS) ischemia during spinal anesthesia is the head up position (3).

**Effects on Other Organ Systems and Metabolism**

Reports from the literature indicate that as mean arterial pressure decreases
below 80 to 85 mm Hg during spinal anesthesia, renal blood flow, glomerular
filtration, and urinary output decrease in a linear fashion (49-51). The kidney
is able to tolerate hypotension quite well and when perfusion pressure is
returned to normal, renal function also returns. Precise data are lacking on how
low blood pressure may go with high spinal anesthesia before irreversible damage
becomes apparent. However, it should be assumed that below a mean pressure of 35
mm Hg renal ischemia and permanent renal damage will occur (3). In patients with
renal vascular disease, this critical level of hypotension may be much higher.

Hepatic blood flow is reduced during spinal hypotension (49-51). Whether this is
due to a reduction in cardiac output or to a redistribution of blood flow away
from the liver is not clear. However, there is no correlation between reduction
in hepatic blood flow and development of postoperative hepatic dysfunction.
Greene, et al (49) found that hepatic function following spinal hypotension with
systolic pressures of 60 mm Hg or lower was similar to that found among patients
who had received spinal anesthesia and maintained normal blood pressure. He
concluded that the reduction in hepatic blood flow produced by moderate
hypotension for a moderate period of time during spinal anesthesia does not
contribute to postoperative changes in liver function (3).

Hypotension associated with spinal block is usually not followed by
significant changes in electrolytes and hematological values. Metabolism and
oxygen consumption are decreased, and the pO[sub 2], pCO[sub 2], pH, and
other biochemical parameters remain normal, except when severe hypotension
persists (3, 52). In a study of parturients who had received subarachnoid block
for cesarean section, Stenger and his associates (52) found that oxygen
capacity, oxygen saturation, and oxygen tension of those in whom severe
hypotension remained uncorrected were the same as those in whom the hypotension
had been corrected. This lack of serious metabolic alteration contrasts with the
significant biochemical changes associated with hypovolemic hypotension (shock).
In hypovolemic shock, there is elevation of serum lactate, pyruvate, and
potassium due to tissue hypoxia and consequent abnormal capillary permeability
and anaerobic metabolism. This difference in biochemical effects is caused by
the different effects on the peripheral vascular bed produced by the two
hypotensive conditions.

**Effects on Labor**

Mild to moderate hypotension has little or no effect on the intensity or
frequency of uterine contractions; however, severe hypotension has been
associated with decreased uterine activity. Vasicka and associates (53) found a
consistent correlation between maternal hypotension and decrease in uterine
contractility. Although this observation has not been uniformly reported, it
stands to reason that if sufficient hypoperfusion is allowed to occur, the
uterus will be deprived of sufficient substrate to meet the metabolic demands of
the contracting uterus. Schellenberg (54) has proposed that supine positioning
with decreased uterine perfusion accompanying aorto-caval compression may have
been a confounding factor resulting in decreased uterine activity in a number of studies assessing the effect of epidural anesthesia on the outcome of labor.[/]

[**Effects on the Fetus and Newborn**][1]

Maternal organ systems will tolerate moderate degrees of hypotension quite well; however, because the uterus is essentially a nonautoregulating organ (55), uterine blood flow will decrease linearly with decreased perfusion pressure. Because of this, the placenta may be inadequately perfused while the parturient remains asymptomatic. It is difficult to predict at what maternal blood pressure level fetal asphyxia will develop. It appears that the uteroplacental anatomy, the normal maternal blood pressure, and the duration of hypoperfusion are all critical. Ebner, et al (56) studied the influence of degree and duration of spinal hypotension on the fetal heart rate. They observed a progressively greater incidence of fetal bradycardia when the maternal systolic blood pressure was less than 70 mm Hg. Even when maternal blood pressure was between 70 and 80 mm Hg for longer than 4 minutes, there was a progressive increase in the incidence of fetal bradycardia. Hon and associates (57), using electronic fetal heart rate assessment, found that maternal hypotension of less than 100 mm Hg systolic for longer than about 520 minutes resulted in signs of fetal distress. Others have reported a decrease in fetal scalp pH (37) and low Apgar scores (58) with maternal systolic blood pressures of less than 100 20 mm Hg for periods as short as 5 to 15 minutes. From these data one can conclude that a systolic blood pressure of less than 100 mm Hg in a previously normotensive parturient should be treated promptly. In such instances, if the hypotension is promptly corrected, it has no effect on the clinical condition of the newborn as assessed by the Apgar score at 1 and 5 minutes and the Neurologic Adaptive Capacity Score (NACS) at 15 minutes, 2 hours, and 24 hours of age (59). On the other hand, in patients who are hypertensive, signs of fetal distress often occur at systolic blood pressures greater than 100 mm Hg. Conversely, fetuses of mothers who normally have systolic blood pressures of less than 100 mm Hg seem to tolerate this without difficulty.[/]

[**Prevention**][2]

Some decrease in blood pressure is to be expected with spinal or epidural anesthesia in obstetric patients. However, a number of measures can be taken to minimize the incidence and severity of hypotension. All forms of neuraxial anesthesia are contraindicated in the presence of moderate or severe hypovolemia. This, however, may not always be apparent. Blood loss can be chronic or occult, and dehydration or maternal disease can result in nonhemorrhagic intravascular volume depletion. If there is any doubt about maternal intravascular volume status, hematocrit and urine output should be checked. Orthostatic blood pressure determinations may provide an indication of intravascular volume status. In some patients, central hemodynamic monitoring may be necessary to help assess a patient's volume status.[/]

[**Intravenous Infusions**][3]

The single best measure in preventing hypotension before induction of spinal or epidural anesthesia is the rapid infusion of balanced nondextrose containing fluid. Experience has shown that 1500 to 2000 ml of balanced nondextrose containing solution should be infused within 30 minutes of a high spinal or epidural anesthetic in the uncomplicated healthy parturient. Before a low segmental block, such as may be used for labor analgesia, 500 to 1000 ml of solution is usually adequate. The safety of rapid fluid preloading with crystalloid solutions in this setting has been well established (59,60).
Although some recommend the inclusion of colloid solution to increase the time the fluid load remains in the vascular compartment (61), they are more expensive and can have other disadvantages, including anaphylactoid reactions. Dextrose-containing solutions are best avoided because of such adverse side effects as maternal hyperglycemia, fetal hyperglycemia, and subsequent neonatal hyperinsulinemia and hypoglycemia (62). There is also some evidence that such solutions increase the brain's susceptibility to anoxic injury (63).

**Lateral Uterine Displacement**

The importance of maintaining continuous left lateral uterine (LUD) displacement cannot be overemphasized. Simply placing a wedge under the hip provides no guarantee of avoiding aorto-caval compression. Fifteen to 30[deg] of tilt and/or manual displacement of the uterus may be necessary to avoid signs of vascular obstruction. Some patients appear to have a more satisfactory result with right uterine displacement. The importance of attention to uterine displacement during cesarean sections has been demonstrated by improved fetal acid base status and Apgar scores (64).

**Vasopressors**

Some authors have recommended the use of prophylactic intramuscular (65) or intravenous (66) ephedrine administration before spinal anesthesia for cesarean section. But in one study, which included a large series of parturients (583) having cesarean sections performed under epidural anesthesia following prehydration and left uterine displacement, prophylactic intramuscular ephedrine did not seem to provide additional protection against hypotension (67). On the other hand, others have reported that prophylactic ephedrine administration is associated with better newborn outcomes when hypotension was prevented rather than treated (68,69). In addition to the other prophylactic measures mentioned, we recommend giving ephedrine intravenously as soon as a significant downward trend in blood pressure becomes apparent or as soon as the patient complains of symptoms associated with hypotension, e.g., nausea, vomiting, or pallor. Because of the low incidence of hypotension with current methods of continuous epidural analgesia used for labor and delivery, prophylactic ephedrine is not recommended.

**Treatment**

The preventative measures outlined above are often sufficient to prevent moderate or severe hypotension with the induction of subarachnoid or epidural anesthesia. However, if the parturient becomes hypotensive or manifests symptoms associated with hypotension, then the following steps should be taken: 1) place the patient in the full lateral position or further displace the uterus laterally; 2) in parturients ready to undergo cesarean section, place them in a modified Trendelenberg position consisting of lowering the head of the table 5[deg] and raising the legs 30[deg] (70); 3) rapidly administer additional intravenous fluids; 4) administer oxygen; and 5) administer increments of 10 mg ephedrine intravenously as needed.

Ephedrine has been shown to have the least detrimental effect on uterine perfusion and is considered to be the vasopressor of choice in obstetric patients (71). As a rule of thumb, a systolic blood pressure of 100 mm Hg should be used as a lower limit in previously normotensive patients. In the hypertensive patient, any sudden decrease in blood pressure of greater than 20% should be treated. A recent clinical study in which low-risk parturients were treated in accordance with this usual rule of thumb, demonstrated that changes
in maternal blood pressure were not correlated with any signs of fetal distress (72).

**SYSTEMIC TOXIC REACTIONS TO LOCAL ANESTHETICS AND RELATED DRUGS**

A number of systemic reactions can occur during regional anesthesia, including: 1) toxic reaction to local anesthetics; 2) accidental overdose of epinephrine or other vasopressors; 3) psychogenic reaction to the procedure rather than reaction to the drug; and 4) allergic/hypersensitivity reactions to the local anesthetic.

**TOXIC REACTIONS TO THE LOCAL ANESTHETIC**

Systemic toxic reactions to local anesthetics are among the most dramatic and distressing complications in obstetric anesthesia and represent one of the main causes of maternal mortality associated with epidural anesthesia (73). Central nervous system and cardiovascular toxic reactions have long been recognized as complications of local anesthetic overdose or, more commonly, unintentional intravascular injection. However, before the widespread use of long-acting amide local anesthetics such as bupivacaine, these reactions rarely lead to fatal cardiac arrest. In 1979, Albright (74) reported six cases of cardiac arrest following bupivacaine or etidocaine injections. Albright speculated that the long-acting amide local anesthetics may be more cardiotoxic and that resuscitation from cardiac arrest induced by these agents may be more difficult. Since then, he has collected at least 44 cases of maternal cardiac arrests, 30 of which have been fatal (75). Data from the ASA Closed Malpractice Claims Study indicate that convulsion was the single most common critical event that led to serious complications among the obstetric-related claims (76). Of 19 convulsions in the obstetric group of claims, 17 were likely due to local anesthetic toxic reactions with epidural anesthesia. Bupivacaine was the local anesthetic used in 15 of the 17 cases. In the remaining two cases, the anesthetic was not specified. Eighty-three % of the convulsions resulted in neurologic injury or death to the mother, newborn, or both.

**Etiology**

Although systemic local anesthetic toxicity can result from overdose, rapid absorption, or abnormally slow elimination of the local anesthetic, the most common cause is unintentional intravenous injection. Epidural veins become engorged in gravidae because these veins serve as an alternate route for blood return to the heart when the inferior vena cava is obstructed by the gravid uterus. It is not rare for an epidural catheter to enter an epidural vein while the catheter is being advanced into the epidural space. Local anesthetic injected into an epidural vein under these conditions may travel to the heart via the azygos vein at a rate many times greater than when the inferior vena cava is not obstructed (77). It has been suggested that cannulation of epidural veins may be more common with the use of end hole catheters than with blunt tipped multiple side hole catheters. However, the positioning of multiple side hole catheters may be ambiguous because one or more of the side holes may be properly placed while others may be intravascular, subarachnoid, or in some other undesired location. In our experience, as many as 5 to 10% of end hole epidural catheters may enter an epidural vein (in the laboring patient) as judged by the ability to aspirate blood or by repeated test doses positive for intravascular injection.

**Pathophysiology**
Many factors influence the toxicity of local anesthetics. One important factor is the relative potency of the anesthetic. A number of studies have indicated that the seizure-producing potential of a local anesthetic is directly related to its anesthetic potency (78,79). The relationship between anesthetic potency and cardiovascular toxicity is less clear. Liu, et al, (80) using cumulative doses of lidocaine or bupivacaine in anesthetized and ventilated dogs, concluded that the cardiotoxicity was similar to the intrinsic potency of the drugs when hypotension and asystole were used as the endpoint. Since then, a number of other studies using a variety of animal models have demonstrated that bupivacaine has a greater potential for causing cardiac arrhythmias (81-85). In large or excessive doses, all local anesthetics have direct myocardial depressing properties. Typically, increasing local anesthetic plasma concentrations produce progressive conduction block with widened QRS complexes and eventually result in asystole. Bupivacaine, however, differs from other local anesthetics (such as lidocaine) in that it can induce cardiac tachyarrhythmias such as ventricular tachycardia and fibrillation. Research has been directed toward explaining these observations, but the answers are not conclusive. Clarkson and Hondegham (86) have postulated that differential binding properties of local anesthetic at the sodium channel may explain the greater dysrhythmia potential of bupivacaine. Other investigators have emphasized the potential role of the central nervous system in explaining the potential for bupivacaine, but not lidocaine, to induce cardiac dysrhythmias (87,88).

**Effects of Pregnancy**

Many maternal deaths have been associated with the unintentional intravascular injection of local anesthetics during attempted epidural anesthesia in the obstetric patient (75). Part of the reason for this may be the greater epidural blood flow in the pregnant patient. Bromage (89) has postulated that this increased blood flow would result in a more rapid delivery of injected local anesthetic to the heart. Bupivacaine in particular has been associated with many of the maternal deaths from local anesthetic toxicity. Animal studies have shown that many factors may lower the cardiotoxic threshold for bupivacaine including, hyperkalemia (90), hypoxia and acidosis (91), as well as pregnancy itself (92). Morishima, et al (84) showed that the pregnant sheep is more sensitive to the cardiotoxic effects of bupivacaine than the nonpregnant sheep. This appears to be due to decreased plasma protein binding for bupivacaine in the pregnant animal as compared to the nonpregnant animal (92). In addition, it may be more difficult to resuscitate the pregnant patient than the nonpregnant patient because of partial occlusion of the inferior vena cava by the gravid uterus (93).

**Effects of the Mother**

If local anesthetic blood levels increase relatively slowly such as in the case of an anesthetic overdose, rapid absorption, or slow elimination, a predictable series of signs and symptoms may be observed. The patient may first complain of numbness around the mouth, altered taste, tinnitus, and manifest excitement or confusion with slurred speech. The patient may then demonstrate muscular twitches and become unresponsive. This is quickly followed by generalized clonic seizure activity. Typically, seizures are brief although repeated, with interspersed periods of flaccidity. In the case of an accidental intravenous injection, there may be no warning signs, and the patient may immediately demonstrate seizure activity. If the patient has been given an anticonvulsant drug such as a benzodiazepine, barbiturate or a general anesthetic, seizure activity may never occur. The first signs of local
anesthetic toxicity may be cardiovascular collapse. When ventilation is supported during experimental infusions of local anesthetics, the margin of safety between CNS toxicity and cardiovascular collapse is much wider than when ventilation is not supported. Moore, et al (94,95) have demonstrated profound acidosis and hypoxia within 30 seconds following the onset of local anesthetic induced convulsions in humans. This is thought to be due to impaired ventilation during seizure activity combined with the increased oxygen consumption and metabolic work associated with CNS and motor seizure activity. These metabolic changes greatly increase the cardiotoxicity of local anesthetics (91,96).

[h4]Effects on Labor[/h4]

[p]Local anesthetics appear to have little direct effect on uterine activity at typical blood concentrations reached with epidural anesthesia (54,97). However, at much higher concentrations that are reached during toxic reactions, direct effects of the local anesthetic may become apparent. At high blood concentrations, local anesthetics cause vasoconstriction and increased uterine tone resulting in decreased placental perfusion (Figure 16-7)[fig16-7] (98). Unintentional intravenous injections of local anesthetic may result in tetanic uterine contractions and fetal bradycardia (Figure 16-8)[fig16-8].[/p]

[h4]Effects on the Fetus and Newborn[/h4]

[p]Fetal distress usually occurs rapidly in the face of overt maternal local anesthetic toxicity. There are a number of reasons for this. Maternal hypoxia and acidosis, which occur within seconds of a convulsion, rapidly result in fetal hypoxia and acidosis. Tetanic uterine contractions, which may result from the direct action of high local anesthetic blood concentrations, are poorly tolerated by the fetus because of impaired uterine and placental perfusion. Even if a convulsion is avoided and uterine perfusion is not adversely affected, high local anesthetic blood levels will be transferred to the fetus resulting in potential neonatal depression. Finally, neonatal depression may be made worse as a result of benzodiazepine or barbiturate therapy used to treat maternal convulsions.[/p]

[h4]Prevention[/h4]

[p]Obviously, local anesthetic systemic toxic reactions are better avoided than treated. Since the editorial by Albright (74), the anesthesia community has become more aware of the potential problems with local anesthetic toxicity in general and bupivacaine cardiotoxicity in particular. Since 1983, the year that the Food and Drug Administration and the manufacturers of bupivacaine recommended that 0.75% bupivacaine should not be used in obstetrics because of cardiotoxic potential, there have been very few deaths associated with bupivacaine toxic reactions (Albright, personal communication, 1990). A number of steps can be taken to eliminate the risks of serious systemic toxic reactions to local anesthetics. At this point, it is appropriate to reemphasize points made in various chapters of this section of the book: no regional anesthetic procedure should be attempted without having a person to assist, and all equipment and drugs needed to treat various complications must be available for immediate use. Intravenous infusion should have been initiated and running with a large enough catheter to deliver fluids rapidly. Obstetric patients should be monitored with ECG and blood pressure cuff as one would any surgical patient in the operating room. Before initiating a regional anesthetic have all necessary resuscitation drugs and equipment at hand and ready for immediate use. We discourage the use of single dose epidurals injected through the epidural needle. Epidural catheters limit the rate at which anesthetic drugs can be
injected and facilitate incremental injection of local anesthetics. We advocate
the use of single end hole catheters to avoid the potential for some of the drug
to be injected into an unintended area. A test dose should be used to rule out
intravascular placement. Inject epidural local anesthetics in an incremental
fashion, i.e., do not inject more than 5 ml of anesthetic solution at one time.
Use the minimum effective dose and avoid exceeding the maximum recommended
dose.[/]

[p]Before injecting local anesthetic, the catheter should be carefully
aspirated; however, the inability to aspirate blood does not rule out
intravascular placement. To minimize the chances of unintentional intravascular
injection, an effective test dose should be used. In 1970, Bonica and associates
(21) demonstrated that the intravenous injection of 15 to 20 [micron]g of
epinephrine produced a beta-adrenergic effect consisting of an increase in SV
and HR with a consequent increase in CO that, together with the
vasoconstriction, produced hypertension. On the basis of this, it is suggested
that epinephrine together with a small amount of local anesthetic be injected as
a test dose before injecting a full therapeutic dose of local anesthetic. Moore
and Batra (99) carried out a much larger study that showed that 15 [micron]g of
epinephrine, when injected intravenously, resulted in a predictable increase in
heart rate within 20 to 45 seconds. Since then, epinephrine has become the most
commonly used marker for detecting intravenous injection. Data from the ASA
Closed Claims Study shows that in none of the claims involving local anesthetic-
induced convulsions was an epinephrine containing test dose documented
(76,100).[/]

[p]Some have suggested that epinephrine, given intravenously, might have
deleterious effects on uterine blood flow and fetal well-being (101,102). In
addition, heart rate changes seen with intravenous epinephrine might be
difficult to distinguish from the normal variation in maternal heart rate that
may occur with uterine contractions (103,104). While these concerns may be
valid, there are few case reports in the literature linking epinephrine test
doses with adverse outcomes, while the advantages of the epinephrine test dose
have been repeatedly documented (105). Hood and James (101) point out that the
reduction in uterine blood flow caused by intravenous boluses of epinephrine
were of the same magnitude and duration as those which occur with uterine
contractions. Moreover, the concomitant use of 5 to 10 mg of bupivacaine or an
equal anesthetic dose of another local anesthetic in the test dose is very
useful to detect unintentional subarachnoid injection and consequently decrease
the risk of total spinal anesthesia.[/]

[p]Epinephrine test doses should be used with caution, or perhaps not at all, in
patients with uteroplacental insufficiency or in those who have a potential for
an exaggerated response to intravenous epinephrine (e.g., PIH) (106). Some
patients, e.g., those being treated with beta-blockers, may respond with
hypertension and bradycardia (not tachycardia) when epinephrine is injected
intravenously (107,108). Complications can be avoided by identifying these
patients before an epinephrine test dose is administered. Recently, alternatives
to the epinephrine test dose have been proposed, including: a20bolus of plain
local anesthetic solution (109,110), isoproterenol (111), or injecting a small
volume of air and using a precordial Doppler for detection (112). However, more
validation of these techniques is necessary before one can recommend replacing
the epinephrine in local anesthetic solution as test dose. Regardless of the
type of test dose chosen, there is no substitute for close observation of the
patient by someone trained to detect adverse signs and symptoms of local
anesthetic toxicity.[/]
[h4]Treatment[/]

Early symptoms of local anesthetic toxicity should be treated with oxygen administration and preparation for intubation. The occurrence of local anesthetic induced convulsions constitutes an emergency condition and must result in immediate action. The patient must be ventilated with oxygen without delay; the trachea should be intubated to protect the airway from aspiration and to facilitate hyperventilation with 100% oxygen thereby counteracting respiratory and metabolic acidosis. Succinylcholine (80 to 100 mg) will facilitate intubation and stop the motor activity associated with convulsions thereby reducing metabolic work and the progression of acidosis. Conservative doses of a benzodiazepine or a barbiturate can be given to suppress CNS seizure activity; large doses, however, may further depress myocardial function. Animal studies have indicated that when ventilation is supported during experimental infusions of local anesthetics, the margin of safety between CNS toxicity and cardiovascular collapse is much wider than when ventilation is not supported.[/]

Early and effective intervention may prevent the progression to cardiovascular collapse. If a nonperfusing cardiac rhythm has established itself, CPR must be initiated. Studies have shown that it is possible to resuscitate animals after massive bupivacaine infusions (82,113) and that it may not be more difficult to resuscitate animals following bupivacaine-induced, than it is following lidocaine-induced, cardiac arrest (82). It may, however, be much more difficult to resuscitate a pregnant patient than a nonpregnant patient because of impaired venous return to the heart due to partial occlusion of the inferior vena cava by the gravid uterus (93). For this reason, emergent delivery should be performed if resuscitation efforts are not quickly successful (114,115).[/]

There is little information regarding the optimum resuscitation protocols for obstetric patients suffering cardiotoxic events due to local anesthetic. Animal studies would suggest that the most important factor is establishing effective circulation to redistribute the local anesthetic. Toxic blood levels of local anesthetic decline rapidly with effective CPR (82). General recommendations include facilitating blood return to the heart by elevating the legs, infusing fluids rapidly, and maintaining left uterine displacement during CPR. In some case reports resuscitation was not accomplished until after emergent delivery of the infant (114,115). Large doses of epinephrine and correction of acidosis may be required to establish adequate diastolic coronary perfusion pressure. Atropine and large doses of epinephrine may be particularly important in resuscitation from asystole. The optimum treatment of bupivacaine-induced arrhythmias may be different. Based on animal studies, some have recommended treating bupivacaine-induced tachyarrhythmias with lidocaine (116) or with bretylium (117); both drugs, however, may cause further hemodynamic depression. Resuscitation efforts should not be abandoned early and, if necessary, cardiopulmonary bypass should be considered (118).[/]

[**OTHER SYSTEMIC REACTIONS**]*[/]

**Reaction to Vasoconstrictors**[/]

Rapid intake of epinephrine is a common cause of systemic reactions during or following regional anesthesia. The patient experiences palpitation, dyspnea, tachycardia, dizziness, perspiration, pallor, and frequent tremors. Although these reactions simulate mild local anesthetic toxic reactions, epinephrine rarely causes convulsions or disorientation. Treatment consists of a small intravenous dose of a benzodiazepine or fast-acting barbiturate to allay
apprehension. If hypertension is severe, an anti-hypertensive drug should be injected intravenously and titrated to control hypertension.[/]

[h4]Psychogenic Reactions[/]

[p]Some parturients who are scheduled for regional anesthesia and who have not been prepared psychologically by the anesthesiologist become apprehensive and fearful of the procedure per se. As a result, some develop dizziness, faintness, tinnitus, tachypnea, tachycardia, and pallor. This psychogenic reaction frequently occurs as soon as the procedure is started, and in some instances, even before the anesthetic is injected. Some of these patients develop hypotension, particularly if they are sitting, with consequent dizziness and faintness. In parturients with cardiac disease, the hypotensive episode may precipitate cardiac arrhythmia. Treatment consists of reassurance, immediately placing the patient in a lateral recumbent position, administration of oxygen, and atropine, if necessary.[/]

[h4]Allergic/Hypersensitive Reactions[/]

[p]Not uncommonly, patients will be seen by an anesthesiologist claiming "allergy" to local anesthetics. Often this is based on some type of systemic reaction that the patient experienced during a dental procedure. Usually, these responses are due to psychogenically induced vasovagal episodes or due to subjective symptoms from intravenous injections of local anesthetic, often containing high concentrations of epinephrine. A detailed history should be taken to determine the probable cause of the reaction. Often the classic symptoms of allergic or anaphylactoid reaction will not be present. On the other hand, a history of urticaria, angioedema, bronchospasm or airway compromise must be taken seriously.[/]

[p]True allergic reactions to local anesthetics are rare. Most of the reported cases have involved amino ester local anesthetics such as procaine, chloroprocaine, and tetracaine (119). This is not surprising as these drugs are derivatives of para-aminobenzoic acid (PABA), which can act as a hapten and is known to be allergenic in nature. Allergic reactions to the amino amides such as lidocaine, bupivacaine, and mepivacaine are extremely rare but have been reported (120). Some cases of suspected amide local anesthetic allergy have been found to be a result of immunologic reaction to methylparaben, which is sometimes added to local anesthetics as a preservative. The structure of methylparaben is similar to PABA and can cause anaphylactic reactions. Cross-sensitivity does not occur with the two classes of local anesthetic agents. Consequently, if a patient is known to be sensitized to one class of local anesthetic it may be safe to administer a drug of the other class. Intradermal skin testing has been recommended to rule out hypersensitivity reactions (121). Skin testing, however, is associated with a number of problems. False positive reactions are very common, especially with ester local anesthetics. Patients who are truly allergic may develop anaphylactic reactions even from very small doses injected intradermally. For this reason, skin testing should not be carried out without full resuscitation equipment and drugs at hand.[/]

[h2]CARDIAC ARREST[/]

[p]Cardiac arrest in the pregnant patient is without doubt the most dramatic and frightening complication that can occur in obstetric anesthesia. Cardiac arrest occurs when the heart ceases to function as an effective pump. This can be due to cardiac dysrhythmia, asystole, or electromechanical dissociation. The incidence of cardiac arrest in the parturient is not known. Some older reports
suggested that it may have occurred once in every 8000 to 10,000 deliveries (122,123). More recent data from the Confidential Inquiries into Maternal Deaths in England and Wales estimate the incidence of cardiac arrest in late pregnancy at once in every 30,000 pregnancies (124,125). However, it has been suggested that advances in modern medicine and surgery have allowed more women with pre-existing serious medical conditions to become pregnant and thus has increased the likelihood of events that may require cardiopulmonary resuscitation (126).

**Etiology**

Cardiac arrest can occur in the pregnant woman with or without obvious predisposing risk factors. Some of the normal physiological changes associated with pregnancy may increase the risk of cardiopulmonary arrest. In addition to the pregnant state itself, a variety of pathologic conditions and complications of pregnancy may further increase the risk to the parturient. These risks can be compounded by a variety of pre-existing medical conditions that the patient may have. Some predisposing risk factors are listed in Table 2016-2. Cardiac arrest is usually preceded by an identifiable event that leads to the cardiac arrest. A number of such events are outlined in Table 2016-3.

**Prevention**

Although it is not always possible to prevent cardiac arrest in the obstetric patient, careful planning, good judgment, and technical expertise can prevent many of the causes of cardiac arrest. This is facilitated by a cooperative, coordinated effort on the part of all members of the obstetric team. Special emphasis should be given to the following issues:

1. Evaluation of the history and physiologic status of the parturient. Particular attention should be given to pre-existing medical conditions, including allergy to drugs, cardiac and pulmonary disease, and history of problems with prior pregnancies and anesthetics. Current obstetrical problems should be evaluated, including any history of bleeding, signs of preeclampsia, and labor pattern. Medications that the patient has been taking, recreational drug use, and recent oral intake should be reviewed. Available laboratory data should be checked and the need for additional laboratory studies ascertained. Physical examination must be guided by the history but a careful airway examination and cardiac and chest auscultation should always be performed before any anesthetic intervention.

2. The optimum analgesic or anesthetic plan should be chosen for each patient. This will be guided by the physical status and obstetric requirements of the patient, as well as the experience of the anesthesiologist.

3. Constant vigilance. ECG monitoring and frequent blood pressure monitoring should be employed for patients having regional anesthesia for labor analgesia, as well as for patients undergoing surgical procedures. Patients having operative deliveries should also be monitored with pulse oximetry and with capnography if a general anesthetic is employed.

4. It deserves re-emphasis that resuscitation equipment must be immediately available to treat any complication including cardiac arrest. Resuscitation drugs and airway equipment must be in the room when starting any regional anesthetic or general anesthetic. A "code cart" with defibrillator should be available on every labor and delivery unit.
Cardiopulmonary resuscitation (CPR) must be initiated immediately once the diagnosis of cardiac arrest has been made. The American Heart Association has developed algorithms to guide the physician in both basic life support and advanced cardiac life support (ACLS) techniques. These guidelines and algorithms are reviewed and revised periodically to incorporate advances in medical science. All physicians should be familiar with the current ACLS recommendations.

The current life support recommendations for pregnant women are similar to those for any adult patient and emphasize the ABC approach to resuscitation, i.e., airway, breathing, and circulation. Table 16-4 outlines basic CPR guidelines for pregnant women. For effective CPR, it is important that the patient be placed supine on a hard, flat surface. In this position, however, the gravid uterus may completely occlude the inferior vena cava. The adverse effect of partial occlusion of the inferior vena cava on CPR has been demonstrated in animal studies. Tilting the patient to the side improves venous return but makes effective cardiac compression more difficult. For this reason, CPR in late pregnancy must involve some degree of compromise in patient positioning. Recent studies indicate that effective compression forces can be generated with appropriate training when the patient is inclined laterally at angles of 30° or less. Advanced therapeutic interventions such as electrical and pharmacologic therapy must be guided by examination of the patient and electrocardiography. Discussion of the relevant ACLS protocols for various cardiac arrest conditions is beyond the scope of this text. For current standards and guidelines, the reader is encouraged to consult appropriate publications.

Some authors have recommended considering fetal status and viability when making resuscitation decisions in pregnant women. Before fetal viability (approximately the twenty-fourth week of gestation) all efforts should be directed toward saving the mother's life. The fetus may be able to tolerate the stresses of maternal cardiac arrest and full CPR without ill effect. Complete recovery of mother and fetus has been documented after 22 minutes of CPR following massive lidocaine overdose in a pregnant women at 15 weeks gestation. Resuscitation included epinephrine and electrical defibrillation. The patient went on to deliver a healthy neurologically normal infant at 40 weeks gestation.

It has been suggested that because many ACLS interventions may be harmful to the fetus, such interventions should be carefully considered or not used at all in pregnancies with a potentially viable fetus. Cardioversion or defibrillation can potentially result in fetal fibrillation, although this seems to be a very remote concern. Lidocaine and most other antiarrhythmic drugs cross the placenta and can potentially have adverse effects. However, when used in standard doses, there appears to be little adverse effect on the fetus from lidocaine and many other antiarrhythmic drugs. Epinephrine and other vasoressors with potent alpha-adrenergic activity cause uterine vasoconstriction. Administration of these drugs can result in severe fetal distress. It is our opinion, however, that, except in very unusual circumstances, all necessary resuscitative interventions should be made available to the mother even if fetal well-being may be compromised.

Although some have advocated attempting to assess fetal well-being during maternal CPR using external Doppler monitoring or real-time ultrasound (in an effort to guide decision making), we feel that such efforts are
misdirected and interfere with the primary objective, which is to resuscitate the mother. If CPR is not effective in generating a palpable pulse or adequate perfusion pressure or if resuscitation is not successful in 5 minutes, then emergent surgical delivery of the fetus should be considered while CPR is continued. The primary purpose of delivery is to improve blood return to the heart and facilitate resuscitation. Numerous cases have been reported in which resuscitation of the mother was not accomplished until after delivery of the fetus (114,115,134,135). An added benefit of early delivery is the possibility of salvaging a viable infant. Prolonged CPR may only worsen the prognosis of a good outcome for both mother and infant. Delivery should not be delayed even if the infant is known to be dead (134). In most cases, open-chest cardiac compression should only be considered after delivery of the fetus because delivery may result in rapid resuscitation and because the complications associated with emergency cesarean delivery will likely be less severe than those associated with emergency open-chest CPR.

Even a successful resuscitation may result in significant maternal and fetal problems. Potential maternal complications include brain injury, a variety of cardiopulmonary complications, laceration of the liver, uterine rupture, and preterm labor. Fetal complications can include CNS depression from antiarrhythmic drugs, intrauterine fetal demise due to inadequate uteroplacental perfusion or cardiac arrest from maternal defibrillation attempts. If the fetus is delivered during resuscitation attempts, problems associated with prematurity, hypoxia, and acidosis are likely to necessitate intensive neonatal resuscitation. In such circumstances, a neonatologist is an invaluable member of the resuscitation team.

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NEUROLOGIC COMPLICATIONS

UNDULY HIGH SEGMENTAL BLOCKADE

Etiology

Higher-than-anticipated block can be a complication of spinal or epidural anesthesia. Following spinal anesthesia, it may be due either to abnormal spread of the therapeutic dose or to injection of an excessive dose. With epidural anesthesia, the cause is excessive dose or unintentional subdural or subarachnoid injection of the local anesthetic. The most common complication associated with high block is hypotension. In the case of "total spinal anesthesia" loss of consciousness, respiratory insufficiency, and cardiovascular collapse can occur.

There is controversy regarding local anesthetic requirement of pregnant patients having epidural or spinal anesthesia (136). It is generally believed that the epidural and subarachnoid dose requirements of the parturient are approximately one-third those of nonpregnant women (137-139). In the case of epidural blocks, this may be due to wider spread of anesthetic solution because of epidural venous engorgement. Similarly, spinal cerebrospinal fluid (CSF) volume may be reduced, resulting in greater spread of anesthetic solution administered into the lumbar subarachnoid space. Recently, a number of studies have indicated that peripheral neuronal tissue in gravid animals (140) and humans (141) may be more sensitive to the effects of local anesthetics. Although there exists some controversy about the local anesthetic requirements for pregnant patients, it is evident from clinical experience that there can be great variability in the extent of blockade achieved with usual doses of a local anesthetic in parturients. Numerous factors influence the distribution of local anesthetics within the subarachnoid and epidural spaces (142,143). Even
appropriate doses of local anesthetic can result in abnormally high blocks if hyperbaric anesthetic solutions are injected with the patient in Trendelenberg position.\[\]

**Unintentional Subdural Block**

The subdural space is a potential space between the dura and the arachnoid membranes. A number of reports have confirmed the unintentional catheterization of this potential space, as well as delayed subdural migration of an epidural catheter (144 2D147). Subdural injection as a complication of epidural block had been estimated to occur with a frequency of 0.82% (148). Typically, the onset of block is more similar to epidural anesthesia than to spinal anesthesia, and for this reason typical test doses to rule out subarachnoid block may not detect a subdural injection (145). The extent of block produced from a given volume of local anesthetic is, however, usually much greater with subdural injection. It is not uncommon to have spread of block to the cervical level with 6 to 10 ml of local anesthetic solution (145,146). When small volumes of water-soluble contrast media are injected into the subdural space, they rapidly spread over a large number of segments, usually in a cephalad direction. Subdural blocks may be patchy or asymmetric (146). The subdural administration of morphine was reported in the management of a patient with cancer pain (149). The authors noted a significantly reduced dose requirement compared to that required by the epidural route, suggesting the potential for respiratory depression with unintentional subdural morphine administration. In a recent in vivo study, investigators found that the arachnoid is the primary diffusion barrier for opioids traversing the meninges (150). This would suggest that optimum subdural opioid doses may be similar to epidural dose requirements. However, because of the potential for serious respiratory depression, we recommend extreme caution when faced with uncertainty regarding catheter location (150A).\[\]

**Unintentional Subarachnoid Block**

Unintentional dural puncture during epidural placement is a relatively common complication with a reported frequency of 1.6 to 2.9%; (144) however, the frequency can vary widely depending on the skill and experience of the practitioner. It is usually recognized at the time of occurrence and has a high likelihood of resulting in subsequent postdural-puncture headache (PDPH). Unrecognized injection of local anesthetic into the subarachnoid space either through an epidural needle or catheter is a much less common, although a potentially fatal complication if improperly managed. If large volumes of local anesthetic are injected, the result is sudden and massive spinal blockade (total spinal) characterized by severe hypotension, loss of consciousness and apnea.\[\]

**Pathophysiology**

The most common complication associated with high block is hypotension. The hypotension can be sudden in the case of extensive subarachnoid block or can occur more slowly as in the case of subdural or extensive epidural block. If hypotension is severe, loss of consciousness will occur due to CNS ischemia. Accompanying the loss of consciousness is the loss of protective airway reflexes. Nausea and vomiting are commonly associated with hypotension and in the presence of depressed airway reflexes may lead to pulmonary aspiration of gastric contents. If subarachnoid block extends into the cervical segments, respiratory insufficiency can occur from intercostal and diaphragmatic paralysis. However, it is unlikely that the concentration of local anesthetic in the cervical region is sufficient to block completely the large motor fibers of
the phrenic nerve. In such cases, it is more likely that apnea results from hypotension and consequent medullary ischemia (3).[/h5]

[h5]Prevention[/h5]

[p]It deserves reemphasis that before initiating any regional procedure, all necessary equipment for proper airway management and resuscitation be available for immediate use. This means that an intravenous infusion and appropriate monitors (e.g., ECG and blood pressure measuring devices) should be in place and shown to be working before starting the procedure. Supplemental oxygen administration is encouraged. Proper patient positioning is important for any regional anesthetic procedure. For subarachnoid anesthesia using hypo- or hyperbaric solutions, proper positioning is critical. It behooves the practitioner to be aware of potentially decreased anesthetic requirements in the pregnant patient and to take a conservative approach with dosing. Identify and double check the drug and amount to be injected. Maintain continuous verbal contact with the patient. This will aid in prompt diagnosis of ascending paralysis and in detecting signs of cerebral circulatory insufficiency. Frequently check vital signs and progression of block, especially during the first 20 minutes.[/p]

[p]For epidural anesthesia, it is important to use an appropriate test dose (e.g., 30 to 60 mg lidocaine or 5 to 10 mg bupivacaine) to rule out subarachnoid needle or catheter placement. At least 3 to 5 min should elapse for a subarachnoid injection to manifest itself. We discourage the use of single-shot techniques and advocate incremental injection of local anesthetic through an appropriately placed catheter. The epidural block should be initiated slowly with incremental doses (e.g., 5 20ml) of local anesthetic solution. It is advisable to stop and wait approximately 10 minutes after the first 520to 10 ml of local anesthetic has been injected. In the event of a subdural injection, a much greater spread of local anesthetic will become apparent and the potential complications of additional anesthetic injection will be avoided (150A).[/p]

[h4]Treatment[/h4]

[p]The treatment for high segmental block will depend on the extent to which problems associated with this complication manifest themselves. The priorities are to ensure adequate ventilation, protect the airway, and to maintain adequate perfusion pressure. In the event of a high epidural or subdural block, the onset may be relatively slow and extent of the block may be such that careful observation, fluid administration, and reassurance are all that is required. Motor strength in the upper extremities must be checked frequently to assess progression of the block.[/p]

[p]The sudden onset of a "total spinal" constitutes an anesthetic emergency. To avoid catastrophic consequences, the airway must be immediately secured and effective ventilation established. Blood return to the heart must be facilitated by lateral uterine displacement, placing the patient in the 5[deg] head down position and raising the lower limbs, and rapid intravenous fluid administration. Under no circumstances should the patient be placed in a head up position in an effort to stop further upward spread of the block (1,3). Vasopressors should be used as required to restore adequate perfusion pressure. In the event of cardiovascular collapse, cardiopulmonary resuscitation must be immediately initiated as outlined above. If the "total spinal" was due to the injection of a large volume of local anesthetic into the subarachnoid space, one should consider draining cerebrospinal fluid to decrease elevated subarachnoid pressure with the associated risk of spinal cord ischemia and to minimize
potential neurotoxic effects from high concentration of local anesthetic (1,151).

[HEADDACHES]

Headache is a common complaint in parturients. Although headaches are often attributed to anesthesia, especially if a regional anesthetic was employed, there are many causes of headaches in the peripartum period (152). Well recognized headache syndromes (e.g., migraine, cluster headaches, and tension headaches) are often modified by pregnancy and may be exacerbated in the early postpartum period. The syndrome of postpartum headache occurs in 30 to 40% of women by the end of the first postpartum week (153,154). The etiology of these headaches is not known although they are most common in women with a prior history or family history of migraine (83%) (153). Table 16-5 lists some potential causes of headaches in pregnancy (155). The most common cause of an anesthetic-induced headache is postdural-puncture headache (PDPH). Other potential causes may include meningeal irritation or infection.

[Postdural-puncture Headache]

In the first report on spinal anesthesia published by Bier in 1899, prominent reference was made to the occurrence of headache following the procedure (156). Although nearly a century has passed, headache remains one of the most common complications of spinal anesthesia, especially in obstetric patients. The incidence of PDPH varies greatly depending on the criteria used for diagnosis, the patient population studied, and the technique used for dural puncture. Table 16-6 summarizes data from a variety of older studies (152). More recent studies, however, report higher frequencies even when small gauge needles were used (157,158). Our own data indicate an incidence of about 10% using 25- or 26-gauge Quincke tip needles in obstetric patients (159). When a headache occurs after spinal or epidural anesthesia, it must be considered a potentially serious complication and must be differentiated from other causes of headache in the perinatal period. A study of malpractice claims filed against anesthesiologists providing obstetric anesthesia care found that 12% of the claims were due to headache. This was the third most common injury for which a claim was brought. The only injuries for which more claims were filed were maternal death and newborn brain injury (Table 16-7) (76).

[Etiology and Pathophysiology]

Bier (156) in 1899 first suggested that the headache may be caused by leakage of cerebrospinal fluid through the hole created in the dura. This is still considered to be the primary cause of PDPH. The most convincing evidence is that provided by the experimental studies of Kunkle, Ray, Wolff and their associates (160). In these studies, the acute removal of CSF in upright patients resulted in headache, and when the fluid was reinjected the headache was promptly relieved. Two mechanisms have been proposed to explain the origin of the painful stimulus. If the fluid leak rate is greater than the CSF formation rate, CSF volume will be less than normal. When the patient assumes an erect position, the brain will tend to shift in a caudad direction thereby placing traction on blood vessels and other innervated structures that anchor the brain to the cranium. Pain pathways for the headache include the trigeminal nerve for stimuli originating above the tentorum and the glossopharyngeal, vagus, and upper cervical nerves for stimuli originating below the tentorum. Another theory of mechanism proposes that as CSF volume is decreased, the cerebral blood volume increases proportionately. This results in abnormally dilated cerebral blood vessels, which may be the source of the painful stimulus.
PDPH is characterized as a mild, moderate, or severe discomfort that is dull, aching, or throbbing in nature. It is typically described as being frontal, occipital, or diffuse in location. Frequently, the headache is associated with moderate pain and stiffness of the neck that may radiate inferiorly along the trapezius ridge to the shoulders and down between the scapulae. Other symptoms that may be elicited are photophobia, nausea and vomiting, and visual disturbances. On rare occasions, the headache is associated with cranial nerve dysfunction, resulting in diplopia. PDPH usually occurs 1 to 5 days after dural puncture and characteristically persists for 3 to 520 days. On rare occasion, the headache lasts for months (161,162). The most important characteristic of the headache is that it occurs or is aggravated by sitting or standing and resolves or is improved when the patient lies down. Table 16-8 lists those clinical features found to be most useful in differentiating PDPH from typical postpartum headache syndrome (153,163).

Persistent or atypical headaches following lumbar punctures should be carefully evaluated. Low cerebrospinal fluid pressure associated with PDPH may be responsible for some intracranial pathologic events or may lead to the diagnosis of unrelated conditions. The incidence of spontaneous subarachnoid hemorrhage is five times higher during pregnancy than it is in nonpregnant women (164). Most of these hemorrhages are due to rupture of cerebrovascular aneurysms or arteriovenous malformations. However, dural punctures for diagnostic or anesthetic purposes have been implicated in causing intracranial subdural and subarachnoid hematoma. Three cases of intracranial bleeding have been reported in parturients following accidental dural puncture during attempted epidural anesthesia (165). Sometimes, the evaluation of a headache following spinal anesthesia leads to the diagnosis of a condition unrelated to the anesthetic. In our own practice, we have seen two women with persistent headache following obstetric regional anesthesia who were eventually diagnosed as having pseudotumor cerebri. Others have reported diagnoses of a true intracranial tumor in the course of evaluating a parturient with postspinal headache and abducens nerve palsy (166).

Prevention

The problem of PDPH is better avoided than treated. Anesthesiologists should be familiar with the factors that have been associated with the development of PDPH. The size of the needle used for dural puncture determines the size of the dural rent and consequently the CSF leak rate. Although the incidence of PDPH varies widely in various studies, the greater incidence of headache with larger gauge needles is a consistent observation (Table 16-6). The orientation of the needle bevel to the dural fibers has also been shown to be important in determining the incidence of headache. Greene (167) in 1926 postulated that inserting the bevel parallel to the dural fibers would separate rather than cut the fibers. Laboratory and clinical studies have confirmed a lower leak rate (168) and lower incidence of headache (169) when the needle bevel is inserted parallel to the long axis of the body. The angle at which a needle punctures the dura has been shown to be an important factor in determining incidence of headache. Hatfalvi (170), in a series of over 600 spinal anesthetics using a lateral approach, reported no cases of PDPH. He attributed this to reduced CSF leakage as a result of tangential puncture of the dura. The lower CSF leakage rate was confirmed by Ready, et al using an in vitro model (168).

Needle tip design has long been thought to influence the incidence of PDPH. Greene (167) and Hart and Whitacre (171) each developed noncutting tipped needles to separate instead of cut dural fibers (Figure 16-9). Such
needles have been shown to reduce the incidence of PDPH (Table 16-6). Recently, disposable small gauge conical tipped needles have become available. We have found a significantly reduced incidence of PDPH in obstetric patients using 24-gauge Sprotte (modified Whitacre) needles compared to conventional 25- or 26-gauge Quincke tip needles (159). Other factors associated with PDPH include: gender, higher incidence in females; age, higher incidence in younger patients; number of dural punctures, higher incidence with increased number of punctures; and history of prior PDPH, higher incidence in patients with a previous history of PDPH (172). The obstetric patient is at particular risk of developing PDPH because these patients are young, female, and many will experience a period of bearing down that may increase the headache incidence (173). This latter finding, however, has not been observed by others (174).

### Treatment

Because PDPH usually resolves spontaneously within 1 week, initial treatment can be conservative, consisting of patient education, reassurance, and oral analgesics (e.g., acetaminophen, codeine). However, one must remember that the headache can be incapacitating and significantly impair mother-infant bonding and the parturient's ability to care for her newborn. Bed rest is advisable because of the postural nature of the symptoms, but does not reduce the incidence of headache (175,176). Prolonged bed rest may actually be contraindicated in the postpartum period because of the risk of deep venous thrombosis. In an effort to foster CSF production, fluid intake should be encouraged. This is important because many parturients may be dehydrated in the postpartum period. Tight abdominal binders have been recommended (177) but are often uncomfortable and impractical. Epidural saline, either by bolus injection or preferably by continuous infusion (e.g., 20 ml/hr for 24 hrs) has been shown, in some studies, to be effective in controlling the symptoms of PDPH (173,178,179).

Recently, the use of caffeine has regained popularity in managing PDPH. The cerebral vasoconstrictor activity of caffeine is thought to be responsible for the relief of symptoms, which are seen in about 80% of patients (180). Caffeine therapy has been shown to be an effective and inexpensive treatment both in intravenous and oral forms (181-183). A typical treatment regimen consists of 500 mg of caffeine sodium benzoate given over 4 hours or 300 mg caffeine given orally. One disadvantage of caffeine treatment is that it may result in only temporary relief of symptoms.

The most effective treatment of PDPH is to stop the leakage of CSF with the injection of autologous blood into the epidural space, "the epidural blood patch." The description of the epidural blood patch technique for the treatment of PDPH by DiGiovanni and Dunbar in 1970 (184) was a boon to both patients and anesthesiologists. Epidural blood patch has been shown to be efficacious in 95 to 100% of patients (185,186). Much has been written regarding the optimum volume of blood to use (186-188), the spinal level at which the blood should be injected (189), and the optimal timing of the procedure following dural puncture. In one study, epidural blood patch within 24 hours had a failure rate of 71% compared to 4% if performed after 24 hours (188). However, in another study, prophylactic epidural blood patch was effective at preventing a significant number of PDPH (190). Epidural blood patch has been shown to be effective months after dural puncture (191). Current practice at many institutions is to perform an epidural blood patch 24 to 48 hours after the onset of moderate or severe headache symptoms. Typically, 10 to 15 ml of fresh, aseptically drawn, autologous blood is slowly injected into the epidural
space near the level of the original dural puncture. If the patient complains of paresthesia or of pain between the scapulae, the injection is stopped.[/p]

[p]Because epidural blood patches are simple, effective, and relatively free of serious complications, there is little reason to delay treatment, particularly when headache is severe. However, the injection of blood into the epidural space is commonly associated with backache and mild signs of meningeal irritation. Potential complications, although very rare, include epidural infection, and nerve root compression. The unintentional injection of blood into the subarachnoid space may result in adhesive arachnoiditis.[/p]

[h3]NEUROLOGIC SEQUELAE OF PREGNANCY AND REGIONAL ANESTHESIA[/h3][/p]

[p]Some of these are causally related to the anesthetic while others are coincident with, but unrelated to, the anesthetic. These complications may involve the cranial nerves, the spinal cord and spinal nerves, as well as surrounding structures. Because the mechanisms of injury vary considerably, each is considered separately.[/p]

[h4]Cranial Nerve Palsies[/h4]

[p]A variety of cranial nerve palsies have been associated with pregnancy but by far the most common is idiopathic facial paralysis or Bell's palsy. The incidence of this condition is 17 per 100,000 per year in women of all ages. The incidence during pregnancy and the first 2 postpartum weeks is 57 per 100,000 per exposure year (192). Bell's palsy is caused by an inflammation or compression of the facial (VII) nerve along its course, usually in the temporal bone. It is typically unilateral and results in facial weakness or complete paralysis; if the lesion is proximal to the branching of the chorda tympani, taste is lost in the anterior two-thirds of the tongue. Prognosis for recovery is good if paralysis is partial. The prognosis is less favorable if taste is lost or if the paralysis is complete. Neuropathies of other cranial nerves such as the trigeminal, trochlear, oculomotor, abducens, and optic nerve have been reported in pregnancy but are very rare and usually mild (192).[/p]

[p]Cranial nerve dysfunction is a recognized but uncommon complication following spinal anesthesia. The incidence of this complication cited in the literature varies considerably. Thorsen (193) collected from the literature a total of 173 cases in a series of 68,179 spinal anesthetics reported between 1906 and 1947, and included seven cases communicated by colleagues from different Swedish hospitals. Virtually all of these data were obtained from questionnaires without follow-up examinations. Subsequently, Arner (194), using close follow-up in the immediate and long term postoperative period, noted no cases of cranial nerve palsies among 21,230 spinal anesthetics carried out during the period 1940-1950 in the Department of Anesthesiology at the Karolinska Sjukhuset in Stockholm. In the United States, Nicholson and Eversole (195) and Greene (196) also reported no cranial nerve palsies in a combined total of nearly 30,000 spinal anesthetics. Vandam and Dripps (197) reported six cases of abducens nerve palsy in a series of 9277 spinal anesthetics, all of which occurred following the use of 16-gauge needles for continuous spinal anesthesia. Paresis of the abducens (VI) nerve has been reported most frequently. Involvement of the oculomotor (III), trochlear (IV), facial (VII), auditory (VIII), and trigeminal (V) nerves has been less frequently linked to spinal anesthesia (198). The relatively high incidence of cranial nerve palsies that were reported in some studies published before 1950 probably relates to the large gauge spinal needles that were often used at that time. Cranial nerve dysfunction is very rarely seen as a complication of obstetric regional anesthesia today.[/p]
Etiology and Pathophysiology

Almost all cases of cranial nerve dysfunction following spinal anesthesia have been associated with postdural-puncture headache (PDPH). The cause of the neuropathy is thought to be due to the same mechanism that is responsible for the headache, i.e., low CSF volume. The brain is normally suspended in CSF with the only fixed connections to the cranium being bridging vessels and cranial nerves. The falx and tentorum further help to stabilize the brain. When CSF is lost at a faster rate than it is produced, e.g., through a puncture in the dura, then the brain is thought to sag, especially when the patient is upright, thereby placing tension on the bridging vessels and cranial nerves. The abducens nerve is particularly vulnerable because of its relatively long extracerebral course and anatomic position. It emerges near the ventral midline at the junction of the pons and medulla oblongata, then passes superior to the anterior inferior cerebellar artery traveling upward, where it makes a sharp turn over the petrus temporal bone. When the brain is displaced downward, the abducens nerve becomes stretched over the petrus temporal ridge.

The trochlear nerve is vulnerable because it is the most slender cranial nerve with the longest intracranial course. Nerve palsy is usually unilateral and is preceded by headache. It may last from days to months. Symptomatology varies depending on which nerve is effected. When any of the nerves involving extraocular muscle function are involved, the most common symptom is diplopia. Numbness of the face can result from involvement of the trigeminal nerve. Hearing disturbances such as tinnitus, dizziness, and perhaps nausea and vomiting may indicate auditory nerve involvement or perhaps effects on the cochlea, which has a direct connection with the CSF. Cranial nerve symptoms are often orthostatic in nature and are improved when the patient is recumbent.

Prevention

The risk of cranial nerve dysfunction can be minimized by taking those steps outlined below to prevent PDPH. This involves using small gauge spinal needles. If a needle with a cutting bevel tip is used, it should be oriented so that the bevel will be parallel to the longitudinal axis of the spine. As mentioned above, using a shallow angle of needle insertion may further reduce the risk of PDPH and associated complications. Perhaps the single most effective preventative measure is to use the newly available small gauge disposable spinal needles with atraumatic tips, such as Whitacre- and Sprotte-type needles. Because PDPH may be the forerunner of a cranial nerve problem, parturients who develop severe and persistent postural headaches should be encouraged to remain in the recumbent position and the headache actively treated.

Treatment

If a parturient develops cranial nerve dysfunction as a complication of regional anesthesia, she should be encouraged to remain at bed rest. If the patient neglects the symptoms and remains upright, permanent neurologic injury can result. Consultation and diagnostic work-up should be considered to rule out other potential causes of the problem. If the cause is thought to be due to CSF leak and low CSF volume, then an epidural blood patch procedure should be performed as outlined previously.

Spinal Cord and Peripheral Nerve Injuries
Among complications of childbirth, neurologic injury can result from both obstetric and anesthetic causes. Regional anesthesia always carries some risk of neurologic injury. Because of this, a postpartum neurologic deficit in a patient having a regional anesthetic will often focus suspicion on the anesthetic. The obstetric anesthesiologist should, therefore, be able to distinguish among symptoms of pre-existing disease, symptoms attributable to pregnancy or delivery, and complications related to the anesthetic. Postpartum neurologic complications are much more likely to arise from obstetric or natural causes than from peripartum regional anesthesia. The incidence of neurologic complications after regional anesthesia is estimated at 1 in 11,000 (200) to 1 in 20,000 (201), well below the 1 in 3000 that may be expected in parturients not having an anesthetic (202).

**Neuropathies in the Peripartum Period**

Any form of neuropathy may occur in pregnancy. The reader is referred to a number of excellent articles reviewing both the common neuropathies of pregnancy and those associated with the administration of anesthesia in the parturient (192,202-205). Although many neuropathies have unknown etiologies, some are due to unsuspected trauma, excessive weight gain, fluid retention during pregnancy, the hormonal changes of pregnancy, and underlying medical conditions often aggravated by pregnancy. Peripartum polynuropathies are usually the result of one of these factors and are unlikely to be related to anesthetic administration. The differential diagnosis in parturients with diffuse peripheral polyneuropathy is similar to that of nonpregnant women and includes postinfectious polyneuritis, metabolic disease, collagen vascular disease, and drug induced conditions.

Mononeuropathies in the peripartum period can present diagnostic challenges to the anesthesiologist, as these can mimic complications of general or regional anesthesia. Any of the cranial nerves can be affected. [i]Brachial plexus neuropathy[/i] may be due to nerve compression between the clavical and first rib due to the increased weight of the20breasts and abdomen combined with sagging of the shoulder. Sensory loss, and pain and shoulder wasting may ensue. Ulnar neuropathy, sometimes in association with median nerve involvement, has been described in the peripartum period. Full recovery usually follows delivery. Median neuropathy at the wrist (carpal tunnel syndrome), the20most common mononeuropathy in the upper extremity, occurs in 7% or more of parturients (206). Conservative therapy, such as nocturnal wrist splinting, is effective in about 80% of pregnant patients. Surgery is rarely necessary for carpal tunnel syndrome associated with pregnancy but may be necessary if motor weakness develops.

[Lateral femoral cutaneous nerve neuropathy[/i], also known as meralgia parasthetica, can occur during the course of pregnancy (207,208). Symptoms of hypalglesia or dysesthesia are seen over the lateral aspect of the thigh. As this nerve is purely sensory, there is no associated motor impairment. Symptoms usually begin in the last trimester of pregnancy (207). The lateral femoral cutaneous nerve has a very long course and thus may be stretched by the increased weight and exaggerated lordosis of pregnancy (208). The exact cause of damage to the nerve is unknown but injury may occur within the pelvis, as it passes beneath the inguinal ligament, or at the fascia lata. Symptoms may persist permanently, but most often resolve within 3 months after delivery.

[Femoral neuropathy[/i] occurs due to injury during vaginal delivery, cesarean section, hysterectomy, or other lower abdominal surgical procedures (209-211). This nerve is vulnerable to compression from retractors positioned
against the greater psoas muscle, hemorrhage into the iliopsoas muscle causing nerve compression, and from trauma as it exits the abdomen next to the femoral artery. The prognosis is good in most cases; however, on occasion there may be pain and persistent weakness for several months. [i]Obturator neuropathy[/i] is rare but may be caused by a difficult labor, hematoma, or by compression from the fetal head or high forceps.[/]

[i]Sciatic neuropathy[/i] may occur during pregnancy particularly during the last trimester as the sacral plexus is compressed by the fetus (211). Pain is sometimes severe enough to warrant bed rest. Permanent injury is rare and symptoms usually resolve quickly after delivery.[/]

[i]Lateral peroneal neuropathy[/i] is due to compression as it crosses the fibular head by poorly positioned leg supports, resulting in foot drop (192). Another cause of foot drop is compression of the lumbosacral trunk as it crosses the sacral ala, which form the posterior brim of the true pelvis (Figure 16-10)[fig16-10]. This injury is likely in short primigravida with a platypelloid pelvis, particularly following prolonged labor and midforceps delivery. Foot drop, in these circumstances, is usually unilateral and on the same side as the infant's brow. Prognosis is good for complete resolution of this injury.[/]

[h4]Bladder Dysfunction[/h4]

[i]Bladder dysfunction is frequently seen in the obstetric patient. Although bladder symptoms are common during pregnancy, neurologic lesions causing these symptoms are infrequent. Prolonged pressure on the pelvic nerves by the fetal head in the second stage of labor or during a difficult delivery can lead to partial denervation of the bladder, resulting in a hypotonic, distended bladder with frequency, and postvoid residual volume. In one study, the incidence of bladder dysfunction following delivery was 2 to 420 times greater following forceps delivery compared to spontaneous delivery (212). There was no difference in the incidence when regional anesthesia was used.[/]

[h4]Backache[/h4]

[i]Backache is frequently attributed to spinal or epidural anesthesia. Grove (213) investigated the incidence of backache following nonepidural vaginal deliveries and found it to be 40% in patients with spontaneous deliveries and 25% in patients with instrumented deliveries. Crawford (212) found the incidence of backache to be 45% in parturients having epidural anesthesia, which is similar to the incidence reported in Grove's study. A more recent study in one British hospital wherein nearly 12,000 deliveries were performed, revealed that backache lasting for more than 6 weeks occurred in 10.5% of women delivered by natural childbirth (214). A similar incidence occurred after delivery by elective cesarean section, whether general or regional anesthesia was used. However, in gravidae who had had epidural analgesia for labor and vaginal delivery or forceps delivery, the incidence of prolonged backache rose to near 19%. Bromage (215) attributed this highly significant difference to ligamentous damage arising from tolerance of potentially damaging posture and straining movements in the presence of analgesia produced by relatively high (0.375 to 0.5) concentration of bupivacaine, which was used by British anesthetists at the time.[/]

[i]Although the incidence of lumbar disc disease during pregnancy is unknown, radicular pain is relatively common. Radicular symptoms have been noted to appear during pregnancy or early puerperium in 39% of parous females with surgically proven, lumbar disc protrusions, most often involving L5-S1 discs[/i]
Symptoms may occur at any time during pregnancy, labor, delivery, or early postpartum period. Treatment should consist of strict bed rest, local heat and massage, and analgesics. If sphincter function is impaired or if pain and motor weakness persist for more than 2 weeks, then neuroradiologic study and surgery may be indicated.

### Anesthetic Related Neuropathies

#### Etiology and Pathophysiology

Neurologic injury due to regional anesthesia can be the result of a variety of causes. A review of cases that have been reported in the literature reveals that the complications may have been due to one or more of the following factors: 1) direct needle trauma during the procedure; 2) neurotoxicity from drugs or contaminants; 3) infection; 4) spinal hematoma; 5) spinal cord ischemia due to vasoconstrictors; and 6) exacerbation of pre-existing disease. Spinal hematoma, infection, and chemical neurotoxicity will be addressed separately in the following sections.

Failure of anesthetic block to resolve as expected may sometimes be related to local anesthetic effects. Prolonged neural blockade due to local anesthetic action must be considered with any of the local anesthetic agents used for spinal or epidural anesthesia. However, prolonged neural blockade (greater than 48 hours), to our knowledge, has only been reported following repeated epidural injections of bupivacaine for labor (215,217,218). The extended duration of blockade has been attributed to accumulation of highly lipid-soluble agents. The block usually resolves without long-lasting untoward effects.

Trauma to neural tissue from spinal or epidural needles and catheters is extremely rare (200,219). If nerve roots are injured, signs and symptoms are found at the spinal segment(s) involved. Sensory roots are more likely to be affected than motor roots. Nerve root injury is more common after spinal than after epidural anesthesia. Direct trauma to the spinal cord can be avoided if dural puncture or epidural placement is below the conus medullaris. The conus medullaris is usually located above the L1-L2 interspace but in some instances may extend to the L2-L3 interspace. Nerve root trauma is usually indicated by severe lancing radicular pain with needle placement.

Epidural and intrathecal catheters are also suspected of causing trauma to spinal roots, although there is little objective evidence in the literature of trauma caused by epidural catheters. In recent years, 26- to 32-gauge spinal microcatheters that can be passed through 25- or 26-gauge spinal needles became available. These catheters showed promise for increasing the popularity of continuous subarachnoid anesthesia in obstetrics. However, in May of 1992, the FDA issued a safety alert and removed these catheters from the market. A report by Rigler, et al described four cases of cauda equina syndrome following continuous spinal anesthesia (220). Microcatheters were used in three of these cases. The authors speculated that maldistribution and relatively high doses of local anesthetic exposed neural tissue to toxic concentrations of anesthetic. Laboratory studies using spinal cord models lend support to this theory (221-223). In addition, the breakage of microcatheters during removal has been reported. The future of small subarachnoid catheters in anesthesia is uncertain at this time.

Ischemic injury to the spinal cord can occur from direct action of excessive high concentration of epinephrine in the local anesthetic solution, especially if the anesthetic is associated with significant hypotension. The blood supply
to the lower part of the spinal cord may be quite tenuous in some individuals. In patients in whom the blood supply is already compromised by disease or anatomic factors, vasoconstrictor effect, together with hypotension, may cause sufficient ischemia in the spinal cord to produce an anterior spinal artery syndrome or transverse myelitis (199).

Many complications associated with regional anesthesia in obstetrics have been attributed to exacerbation of pre-existing neurologic disease (224). In some cases, the relationship seems quite obvious, e.g., a patient with a bleeding dyscrasia who develops a spinal hematoma following an epidural anesthetic. In other cases, the relationship is purely speculative, e.g., worsening of neurologic symptoms in a patient with multiple sclerosis. In a study of 10,098 patients, Vandam and Dripps found 11 cases in which the anesthetic may have exacerbated pre-existing disease (224). The cases included meningioma, viral diseases affecting the nervous system, patients with metastatic tumors, and two elderly diabetic patients. Several neurologic diseases (e.g., multiple sclerosis) may be exacerbated in the postpartum period, which may implicate any anesthetic that was given for labor and delivery. Although a cause and effect relationship between regional anesthesia and exacerbation of pre-existing disease may be only speculative, it may be prudent to avoid regional anesthesia in such patients. However, this should not be considered an absolute contraindication, especially in cases in which the advantages of regional anesthesia are clear and the patient is informed and has given consent.

The most important means of avoiding spinal nerve injury are to rigidly adhere to the basic principles of good regional anesthesia. Patients should be carefully evaluated before regional anesthetics. Those who refuse or who are reluctant to have spinal or extradural anesthesia should not be forced to undergo the procedure. The risks and benefits of regional anesthesia should be carefully weighed in patients who have systemic disease that may involve the nervous system.

To avoid contamination, it is best to use disposable needles, syringes, and catheters. The packaging should be carefully checked to ensure sterility and up-to-dateness. Regional anesthetic techniques must be carried out under strict aseptic conditions. Care must be exercised to avoid contamination of the local anesthetic by the antiseptic solution. The local anesthetic and any other drugs must be accurately identified and the lowest therapeutic amount and concentration used. Solutions that have become turbid or that contain undissolved crystals should be discarded. Vasoconstrictor drugs should be avoided in patients with vascular disease. The anesthesiologist should not persist beyond reasonable attempts to place a regional block. If the patient experiences paresthesia during puncture or injection of the drug, the needle should be withdrawn and repositioned. If paresthesia persists, it is best to discontinue the procedure.

The anesthesiologist should have an organized and thorough approach to the patient presenting with neurological symptoms. Appropriate questions to ask include: what is the nature of the symptom (sensory, motor, both; unilateral, bilateral)?; what is the location of the suspected lesion? can it be explained on an anatomic and physiologic basis?; does it follow a peripheral nerve distribution or a spinal segmental distribution?; are there related medical...
conditions that might explain the symptoms?; are there circumstances surrounding
the pregnancy, labor, and delivery that might be the cause of the suspected
lesion (i.e., protracted labor, difficult or instrument delivery, cesarean
section and use of retractors)?; and were there any difficulties during the
anesthetic that might explain the lesion?[/]

[p]A careful physical examination should document any sensory and motor deficits
as either segmental or peripheral. The results of the history and physical exam
will dictate the need for additional consultation and diagnostic tests.
Electromyography, nerve conduction studies, and somatosensory evoked potentials
may be helpful in localizing the lesion and determining a prognosis.
Electromyography should be conducted immediately after the injury becomes
apparent and again 2 to 3 weeks following the injury. This can help
differentiate new injury from pre-existing lesions because it takes about 2
weeks for electromyographic denervation potentials to appear.[/]

[p]Treatment for acute neurologic injury is primarily supportive, including good
nursing care and rehabilitation therapy. Prognosis depends on the type and
extent of injury. Neuropractic injuries involve damage to the myelin sheaths
surrounding axons. Prognosis for recovery with such injuries is excellent, as
the myelin sheaths are repaired over a period of weeks. In the case of
neurotmesis, axons have been damaged and Wallerian degeneration occurs. The
prognosis is poor because the axons must regenerate along the length of the
nerve, a very slow process that is rarely complete (225).[/]

[h3]Spinal Hematoma[/]

[h4]Etiology and Pathophysiology[/]

[p]Spinal hematoma formation whether epidural, subdural, or subarachnoid can
result in devastating neurologic injury. Such hematoma may occur spontaneously
without any apparent precipitating event or condition. They can occur at any age
and at any spinal cord level (226,227). Sudden spinal cord compression caused by
spontaneous epidural hematoma without evidence of a pre-existing vascular
anomaly has been reported during pregnancy (228,229). Risk factors for spinal
hematoma formation include coagulopathy, trauma, spinal tumors, and vascular
malformations.[/]

[p]The potential risks of epidural, subdural, or subarachnoid hematoma caused by
neuraxial blocks or diagnostic lumbar punctures seem obvious, although it is
difficult to quantify such risk. Neuraxial hematoma formation has been reported
following epidural anesthetics and lumbar punctures, usually in association with
anticoagulation therapy (226,230). The incidence of this complication is unknown
but is very low. Spinal hematoma are more likely to be spontaneous than to be
associated with epidural anesthesia (225).[/]

[p]Spinal hematoma of any type can result in cord compression and cord ischemia.
The presenting symptom is usually severe localized back pain, sometimes with a
radicular component. This is usually followed by rapidly progressing sensory
loss, paraplegia, and bladder and bowel dysfunction. Sometimes signs and
symptoms may progress more slowly, making diagnosis more difficult. Except for
subarachnoid hemorrhage, CSF analysis is not diagnostic and, consequently, of
little help. Computed tomography, magnetic resonance imaging, and myelography
are the most useful studies to confirm the diagnosis.[/]

[h4]Prevention[/]
Coagulopathy has been considered an absolute contraindication to regional anesthesia in the obstetric patient (231). This is especially true for labor analgesia in which there may be no clear medical indication for the procedure other than the relief of pain associated with a normal physiologic process (i.e., labor and delivery). A significant number of parturients without any known risk factors may present with thrombocytopenia (232). Furthermore, a number of conditions such as preeclampsia, infection, autoimmune disease, etc., are associated with low platelet counts. For these reasons, the obstetric patient may be at increased risk of spinal hematoma formation. However, we are not aware of any case reports in which a regional anesthetic procedure in an obstetric patient with thrombocytopenia resulted in neurologic injury as a result of spinal hematoma (233). However, this may be because regional anesthetics are avoided in such patients, or because such cases have not been reported in the literature. 

Anesthetic interventions in obstetric patients are frequently required on an urgent or emergent bases, often before laboratory results and coagulation studies are available. Retrospective studies have indicated that many parturients have received neuraxial anesthetics with platelet counts that are considerably below normal (233,234). This can be a particular problem in preeclamptic women who, in addition to thrombocytopenia, often have a defect in platelet function, which can prolong bleeding time (235). None of the above studies have found neurologic injury as a result of spinal hematoma even in the obstetric patient at risk. A review of the ASA closed-claims data base containing over 250 malpractice claims involving obstetric anesthesia for the years 1976 to 1989 found no claims related to spinal hematoma formation. Although spinal hematoma is a devastating complication, the incidence appears to be exceedingly low. Prudence dictates avoiding regional anesthetic procedures in parturients with abnormal coagulation parameters; however, in cases where conduction anesthesia offers particular advantages, the benefits may outweigh the potential risks (233).

Treatment

Evolving spinal cord compression constitutes a surgical emergency necessitating immediate decompressive laminectomy. Osmotic diuretics and steroids have been used as adjuncts. The severity of preoperative symptoms and time from first symptoms to surgery influence the prognosis. For this reason, neurosurgical consultation should be immediately obtained if spinal hematoma is suspected.

Spinal Infection

Etiology and Pathophysiology

Spinal infection can be the result of poor aseptic technique while performing the regional anesthetic block. Skin infections near the site of needle insertion may allow spread of infection to the epidural space or to the subarachnoid space. Vascular trauma during regional procedures may allow blood-borne organisms to seed infection in the epidural or subarachnoid space, resulting in epidural abscess or meningitis. The potential for spreading infection to the neuraxis has been the main contraindication to regional anesthetic techniques in patients with active infections.

Epidural abscess is usually the result of osteomyelitis or spontaneous hematogenous spread (236). The spontaneous occurrence of a Staphylococcus aureus epidural abscess has been reported in the postpartum period (237). The risks of
epidural abscess due to neuraxial anesthesia are very low. One estimate places the incidence at less than 0.0015% (238). Most cases related to regional anesthesia were reported in the early days of caudal anesthesia for labor (239). Epidural abscesses may be more common when catheters are left in place for prolonged periods such as for chronic pain management or when epidural steroids are also injected (240).

Meningitis following regional anesthesia is also rare, although three cases were recently reported in association with epidural anesthesia. One case may have involved the introduction of blood-borne bacteria into the CSF during unintentional subarachnoid puncture or during a subsequent blood patch procedure (241). The second case involved an uncomplicated epidural for labor and delivery with subsequent meningitis caused by a bacteria common in dental carries (242). In the third case, introduction of bacteria from the skin surface may have been the likely cause of meningitis (242). In another recent case report, meningitis was described following obstetric spinal anesthesia for removal of a retained placenta (243). In that case, it was not clear whether the etiology was due to chemical irritation or a partially treated bacterial infection. Although such cases are very rare, the potential for neuraxial infection, either introduced from the skin or from organisms in the blood, must be considered.

Signs and symptoms of acute bacterial meningitis include fever, headache, nuchal rigidity, Kernig's and Brudzinski's sign, altered mental status, and convulsions. Diagnostic lumbar puncture reveals elevated cerebrospinal fluid pressure, CSF pleocytosis, elevated CSF protein, and depressed CSF glucose. CSF cultures will usually be positive for the offending organism. Epidural abscess presents with fever and localized pain and tenderness, sometimes with a radicular component. If not promptly diagnosed and treated, lower extremity weakness and sphincteric dysfunction develop over a period of days to weeks. CSF examination may reveal elevated protein and moderate pleocytosis but may be otherwise unremarkable.

Prevention involves using strict aseptic technique, avoiding inserting needles near areas of superficial infection, and avoiding neuraxial anesthetic procedures in septic patients. The cerebrospinal fluid is an excellent culture medium and the subarachnoid space has limited defenses against infection. The person performing the block should wear cap and face mask as well as sterile gloves. Breaks in sterile technique should not be ignored or treated lightly. The back should be prepared with antiseptic solution in the proper manner. Because chemical arachnoiditis has been caused by antiseptic solutions, it is important to wipe the skin before the needle is introduced. When performing a spinal anesthetic, it is advisable to use an introducer through which the spinal needle can be directed. This prevents the spinal needle from coming into direct contact with the skin. The introducer also acts as a guide and prevents the needle from deflecting. The operator should avoid holding or touching the part of the needle that will enter the subarachnoid space, thereby diminishing the risks of contaminating the needle.

The use of regional anesthesia in patients with chorioamnionitis is controversial (244). Because these patients frequently have positive blood cultures, the risk of seeding infection is a possibility (245). Many anesthesiologists will, however, initiate regional anesthetics if parturients are not grossly septic and are receiving antibiotic therapy when the procedure is initiated (246). This practice has not resulted in reports of epidural abscess or meningitis.
Similar concerns about spreading infection by needle trauma have been raised in pregnant patients with herpes infections. Herpes simplex virus type 2 (HSV-2) is an increasingly common infection in women of childbearing age. In the greater-Seattle area, approximately 30% of women of childbearing age are seropositive for HSV 2D2 and 8 to 10% have symptoms consistent with recurrent outbreaks (Brown ZA, personal communication, 1990). Approximately 30to50% of women with a history of recurrent HSV2D2 infections are delivered by cesarean section. (247) Regional anesthesia seems to be safe in patients with recurrent HSV 2D2 infections (248,249) perhaps because recrudescence is not associated with viremia. However, because primary infections are associated with viremia and often severe generalized symptoms such as fever, lymphadenopathy, and headache, we advise avoiding regional anesthesia in patients with primary infections.[/]

**Treatment**

Treatment for spinal infections consists of rapid initiation of intravenous antibiotic therapy. This should be based on the type of organism responsible for the infection and sensitivity studies, although initiation of antibiotic therapy should not be delayed. Analgesics, antipyretics, and sedatives are used as necessary. Anticonvulsants may be required in some cases of meningitis. Epidural abscess usually requires prompt surgical intervention to decompress the spinal cord and remove infected and necrotic tissue.[/]

**Chemical Meningitis and Neurotoxicity**

**Etiology and Pathophysiology**

Meningeal irritation and neurotoxicity from clinically used concentrations of local anesthetics are extremely rare. Drug manufacturers go to great lengths to ensure that their products cause a minimal amount of local tissue reaction. Nonetheless, it is clear that virtually all local anesthetics in sufficiently high concentration will cause injury to nerve tissue (250,251). Case reports have linked neurologic injury from spinal anesthesia with a20wide variety of local anesthetics (252), although it has not always been clear if the local anesthetic or a contaminant was the cause of the injury. In the past, detergents and other solutions used for cleaning reusable needles and syringes have been implicated in causing aseptic meningitis and neurologic injury (253). One of the most serious potential sequelae is adhesive arachnoiditis. This condition involves a gradual proliferation of the arachnoid, resulting in scarring and obliteration of the subarachnoid space. The signs and symptoms of the resulting caudal equina syndrome may be progressive over months or years and usually involve numbness and weakness in the perineum and lower extremities with bowel, bladder, and sexual dysfunction.[/]

In recent years, the local anesthetic most often linked with neurotoxicity has been 2 2Dchloroprocaine. This agent has been very popular in obstetrics because of its rapid onset, short duration of action, and very low systemic toxicity. In some of the reported cases of neurologic injury, it appears that the local anesthetic was unintentionally injected into the subarachnoid space (254), although this may not have occurred in all cases (255). A20considerable amount of research has been directed at determining if the cause of neurotoxicity was the drug itself or the antioxidant, sodium bisulfite, with which the local anesthetic was formulated to minimize oxidation. Some laboratory (256) as well as animal studies (257) have indicated that the sodium bisulfite was the most likely cause of neurotoxicity. Other studies, however, indicate
that the drug itself may be more neurotoxic than other commonly used local anesthetics (258). Presumably because of the concern regarding sodium bisulfite, the manufacturers now use EDTA as the antioxidant in commercially available 22Dchloroprocaine. The drug continues to be available to the practitioner but due care should be exercised in its use. Recent reports have indicated that the epidural use of the newly formulation 2 2Dchloroprocaine may be associated with severe spasmodic back pain (259,260).

[h4]Prevention[/h4]

[p]All local anesthetics should be used in the appropriate fashion using the minimum dosage necessary for the procedure. Before injecting significant volumes of local anesthetic with epidural techniques, a test dose should be given to rule out subarachnoid as well as intravascular placement. Care should be taken to avoid contaminating needles, catheters, and syringes with antiseptic solutions used for cleaning the skin. In addition, it is advisable to use disposable equipment whenever possible, to minimize the risk of introducing contaminants, such as detergents or cleaning solutions, during regional anesthetic procedures.[/p]

[h4]Treatment[/h4]

[p]The management of chemical meningitis is based on supportive care and treatment of symptoms. Antibiotics are not indicated although they are often started because of diagnostic uncertainty. In cases where an inappropriate drug or a large dose of local anesthetic is known to have been injected into the subarachnoid space, it may be advisable to drain as much CSF as possible to remove as much of the substance as possible and to lower subarachnoid pressure (if large volumes were injected).[/p]

[h3]Shivering[/h3]

[p]Shivering is a minor but annoying accompaniment of labor and delivery in 23% of normal parturients without extradural analgesia (261) and 20 to 75% of women who have extradural analgesia for labor and delivery (215,262). Although it is not a true complication of obstetric anesthesia, shivering can have adverse effects. Metabolic rate and oxygen consumption can increase 200%, thereby substantially increasing the demands on an already stressed pulmonary and cardiovascular system (263). Parturients with cardiopulmonary disease or those with stressed infants may be adversely affected by shivering. In addition to these concerns, shivering can complicate monitoring, heighten anxiety, and add to fear and stress during labor and delivery.[/p]

[h4]Etiology[/h4]

[p]The etiology of shivering during normal labor and delivery is not known, although a number of mechanisms have been proposed. There is a correlation between the occurrence of postpartum chills and fetal-maternal transfusions, although there does not seem to be a correlation with blood-incompatibility (264). A possible immunologic reaction to emboli of fetal or trophoblastic cells has been suggested but not confirmed. Other suggestions include: amniotic fluid embolism, bacteremia or the release of other toxins, maternal thermogenic response to sudden thermal imbalance from the rapid removal of the fetus and placenta, vasomotor reactions, and nervous excitement.[/p]

[p]Epidural-related shivering typically begins 5 to 15 minutes after the injection of the local anesthetic into the epidural space. A variety of mechanisms have
been suggested to explain shivering in association with epidural anesthesia: Vasodilation from sympathetic blockade can result in a drop in core temperature leading to thermoregulatory shivering. The absorption of local anesthetic may cause a nonthermoregulatory tremor or may cause central disinhibition of spinal cord reflexes producing tremors similar to those seen during recovery from general anesthesia. Absorption of local anesthetics may raise the hypothalamic thermoregulatory set point. Differential blockade of warm and cold afferent thermoreceptor fibers at the dorsal roots of the spinal cord may cause shivering. Cold receptors in the epidural space may be stimulated by cold anesthetic solution. A number of recent studies have addressed the likely mechanics involved (263,265-267). At this time, the most attractive hypothesis is that the sympathectomy caused by epidural anesthesia results in peripheral vasodilation leading to central hypothermia and normal thermoregulatory shivering.[/p]

A number of methods have been used in an attempt to minimize shivering during epidural anesthesia in obstetrics. The use of warmed intravenous fluids, warm ambient temperature, and warmed local anesthetic injectate have all been used with variable success (262,265,268,269). Intravenous meperidine 50 mg given at the time of cesarean delivery has been found to be effective in treating this problem (270). Epidurally administered opioids have also been found to be effective in treating and preventing shivering in this setting (262,271-273). In one study, epidural fentanyl 25 mg given prophylactically to patients undergoing cesarean delivery resulted in a 50% reduction in shivering (274). In our experience, the use of epidural lidocaine without epinephrine (except for the test dose), prophylactic epidural fentanyl 50 [micro]g, and warm intravenous fluids has virtually eliminated shivering associated with the onset of epidural anesthesia for cesarean section.[/p]

References[/h1]

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