Prevention of Intrathecal Drug Delivery Catheter-Related Complications

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■ **ABSTRACT**

In an effort to improve the performance of implantable intrathecal drug delivery systems, a group of physicians experienced in the management of such devices reviewed surgical practices and principles that were associated with low catheter-related complication rates. Clinical study and postmarket data identified physicians whose patients experienced a relatively low rate of catheter-related complications. Six of those physicians (three anesthesiologists and three neurosurgeons) reviewed the number and types of intrathecal drug pumps and catheters they had implanted, with an emphasis on the specific details of successful catheter implantation techniques. The authors pooled their experiences to reach a consensus on implant techniques that are associated with a low rate of postoperative complications.

The authors found that complications were minimized by the use of specific methods for catheter placement that included: a mid-to-upper lumbar dural entry level, a shallow-angle paramedian oblique insertion trajectory, and meticulous catheter anchoring and tunneling techniques. Systemic antibiotic prophylaxis, attention to pump pocket location, and surgical wound closure techniques also were important in reducing the incidence of postoperative device-related complications. Their experience indicates that specific implantation techniques using a variety of catheters and accessories can be expected to reduce the incidence of complications after implantation of intrathecal drug administration systems. ■

KEY WORDS: drug administration system, intrathecal catheter, intrathecal drug delivery, pain, pump, spasticity.

INTRODUCTION

Background and Scope

Intrathecal drug delivery using fully implantable pumps and catheter systems has been used since the 1980s to treat chronic intractable pain associated with cancer or nonmalignant causes (1,2). Programmable systems to administer intrathecal baclofen

The consensus conference upon which this manuscript is based was supported by an unrestricted educational grant from Medtronic, Inc., Minneapolis, MN.

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have been in use since 1992 to treat spasticity (3). The principal advantage of intrathecal drug delivery over other routes of administration is that therapeutic agents are delivered near their sites of action within the spinal cord. Delivery near the sites of action avoids the blood-cerebrospinal fluid (CSF) barrier, increases therapeutic efficacy, allows the administration of relatively low dosages, reduces or eliminates systemic spread, and reduces the likelihood of systemic and cerebral side effects. However, the dependence of targeted drug delivery upon the use of implanted medical devices exposes patients to a variety of drug-, procedure-, or device-related complications (4). Regardless of severity, all such complications involve some level of patient risk, inconvenience, and expense. The estimated total charges for a catheter revision or repair can exceed $5000. Patient or physician frustration over repeated difficulties also can discourage the adoption of or continued use of intrathecal therapy by new users or current practitioners, respectively (5). This article addresses ways to reduce the most common and potentially preventable complications related to intrathecal catheter implantation procedures.

METHODS

In an effort to improve the performance of intrathecal drug delivery systems, the authors reviewed the medical literature, unpublished clinical trial and survey data, and their own experiences pertinent to the avoidance of catheter-related complications.

Previous Investigations

In one prospective, multicenter study of 209 patients, 42 complications that were related to catheter implantation occurred (5). The most frequent was infection (15 cases), followed by catheter dislodgement or migration (12 cases, 10 of which were directly related to the implant procedure). A separate review of implantation techniques among 202 patients at 22 centers found that procedures varied considerably, even for a single model of pump and catheter (6). The majority of catheters in the latter review were inserted at the L2-3 or L3-4 vertebral levels (87%), introduced through the midline (65%), anchored to the lumbodorsal fascia (95%), and had the catheter's position confirmed by intraoperative imaging (95%). The study group found no correlation between surgical technique and complications.

In three other clinical trials conducted by Medtronic, Inc. (Minneapolis, MN) catheter-related complication rates varied from 20% to 25% (Indura Model 8703 W Catheter Clinical Surveillance Study, Protocol #D94-046, Final Report October 1998, Medtronic, Inc., Minneapolis, MN; Clinical Study of the SynchroMed Model 8709 Catheter for Long-Term Intrathecal Use, Final Report, November 1997, Medtronic, Inc., Minneapolis, MN; A Randomized Double-Blind, Placebo-Controlled Study to Evaluate the Efficacy, Safety and Tolerability of Recombinant Methionyl Human Brain-Derived Neurotrophic Factor (r-metHuBDNF) when given by Intrathecal Infusion to Patients with Amyotrophic Lateral Sclerosis (ALS), Device Objective Study Report, November 2001, Medtronic, Inc., Minneapolis, MN). For convenience, those trials will be referred to as the 8703 W, 8709, and BDNF trials, respectively. Figure 1 illustrates the aggregate proportion of patients who were affected by the different kinds of catheter-related complications in those trials. The most frequent were dislodgement or migration from the intrathecal space (6.1%), fracture or breakage (5.1%), kink or occlusion (4.0%), and cut or puncture (3.0%). Other catheter complications occurred in less than 1.0% of patients. During a 1- to 2-year follow-up, 80% of catheters in those studies remained complication-free.

Analysis of the Model 8709 trial revealed that procedure-related catheter complications occurred more commonly than purely device-related catheter complications (5). That investigation included anesthesiologist and neurosurgeon implanters. Complication rates varied considerably among centers in the Model 8709 and BDNF trials (Fig. 2A,B). All of the neurosurgical investigators in the BDNF trial implanted approximately the same number of devices, indicating that the complication rate was not related simply to the number of implantation procedures that each surgeon performed (Fig. 2B). This observation suggests that certain features of the implantation procedure caused the catheter complications at centers with higher complication rates. Consequently, the identification and modification of those features of the implantation procedure might reduce the incidence of catheter-related complications.

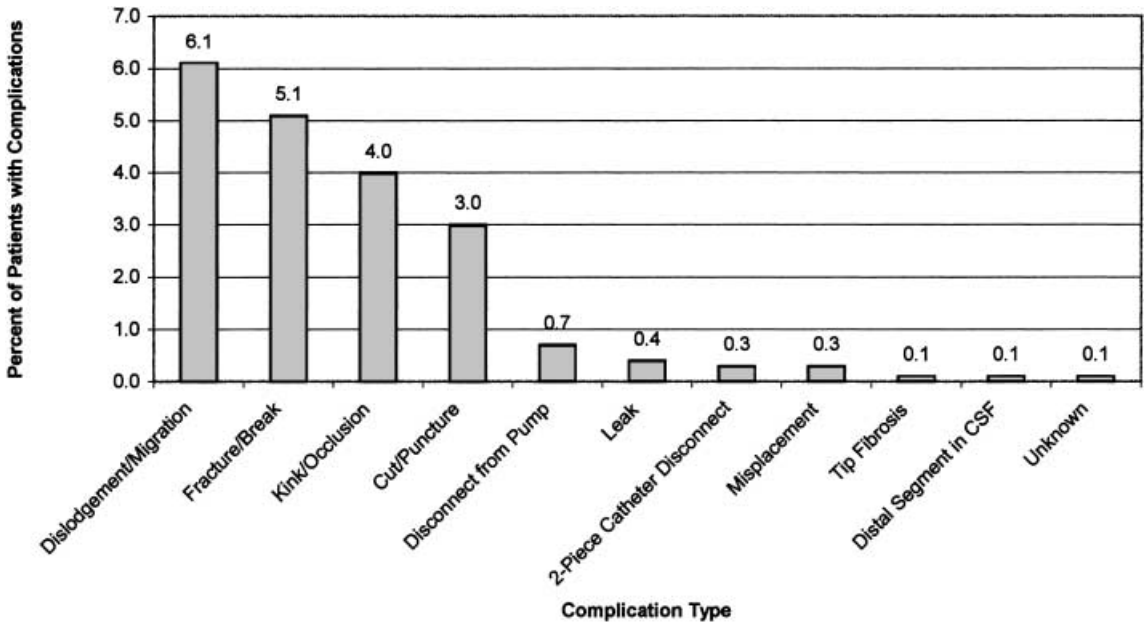

Figure 1. Aggregate catheter-related complication rate in three clinical trials.The aggregate catheter-related complication rate in three clinical trials was approximately 20%. Eighty percent of catheters remained complication-free between 1 and 2 years after implantation.

The Catheter Implantation Consensus Panel

Clinical study and postmarket surveillance data compiled by Medtronic, Inc. (Minneapolis, MN) identified physician implanters of intrathecal drug administration systems whose patients experienced relatively low rates of catheter-related complications. Those physicians were asked to complete a detailed survey about the number and types of systems they had implanted and about specific details of their implantation procedures and techniques.The present authors include six of those physicians (three anesthesiologists: TD, SDP, JP; and three neurosurgeons: KB, KAF, MST) who have a combined experience that involves more than 1500 intrathecal drug administration systems. Three of the physicians use a one-piece catheter, and three use a two-piece catheter.

CONSENSUS STATEMENTS

Venue and Anesthesia for Implant Procedures

Procedures to implant, revise, or repair intrathecal drug administration systems (or any system components) should be performed in a formal operating room setting, either at a hospital or outpatient surgical center. In contrast, treatment or examination rooms in physician office suites are not suitable locations for such procedures. Other qualifications of the implant center include the availability of intraoperative C-arm fluoroscopy and staffing with personnel experienced in the performance of strict aseptic surgical procedures.The use of meticulous aseptic techniques during the implantation procedure is essential to prevent costly and time-consuming complications associated with infection of the infusion system.

The infusion system may be implanted with the patient under general anesthesia, or under local anesthesia with sedation, depending upon the physician's and patient's preferences, and the patient's clinical condition. Whenever possible, it is preferable to insert the needle into the spinal canal below the *conus medullaris*, especially if general anesthesia is used, to minimize the possibility of injury to the spinal cord. Spinal anesthesia can be administered through the catheter once it is properly positioned. Because pump and catheter implantation does not involve entering a body cavity and does not require deep levels of anesthesia, even fragile or infirm patients, such as those with advanced cancer, usually tolerate the procedure safely.

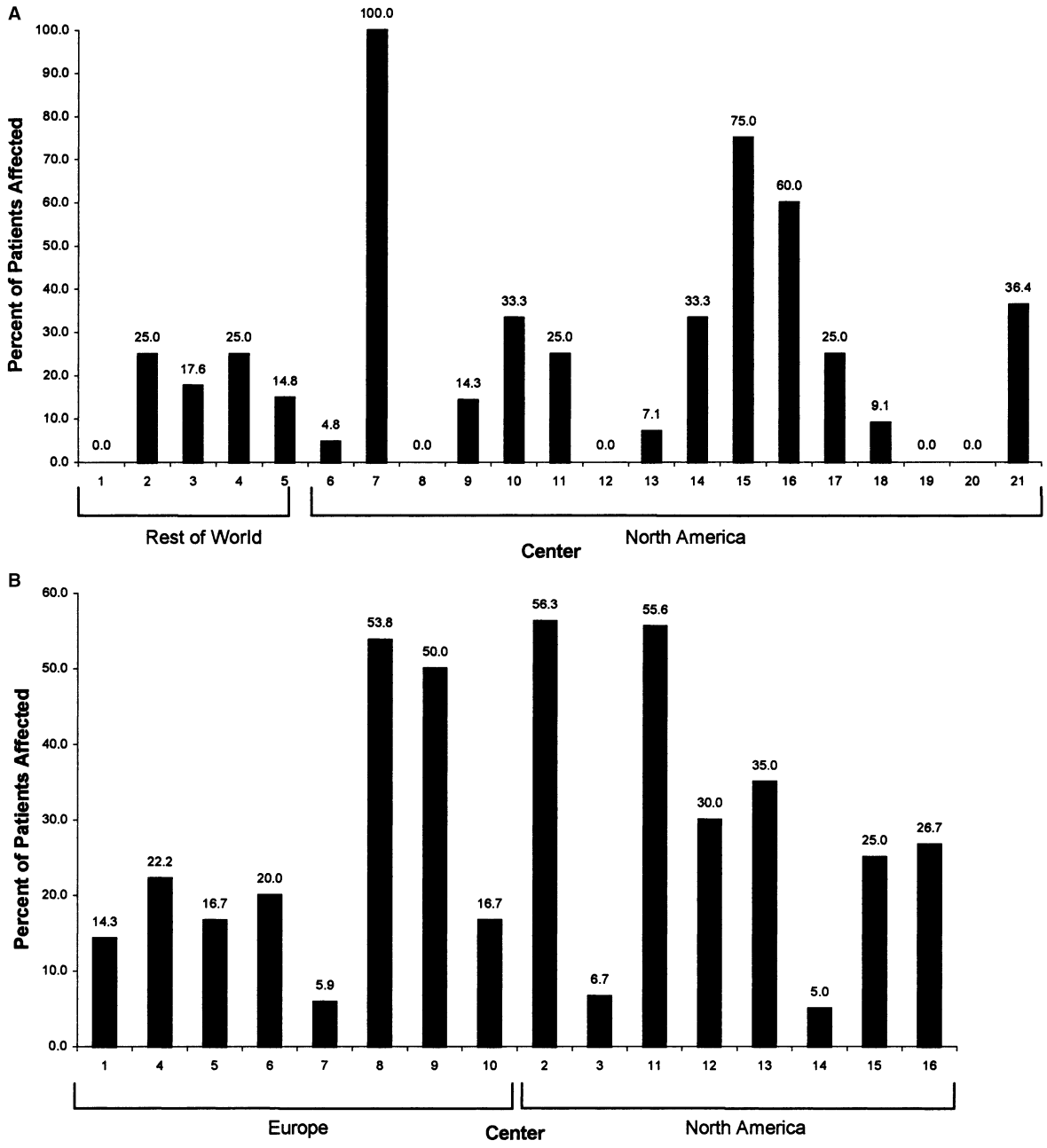

Figure 2. A) Catheter-related complication rates by investigative center in the Model 8709 Catheter trial. Catheter complication rates varied from 0% to 100% among centers in the Model 8709 Catheter trial. Center numbers on the horizontal axis are arbitrary. Abbreviations: OUS, centers outside of the United States; US, centers within the United States. B) Catheter-related complication rates by investigative center in the BDNF clinical trial.All of the investigators in the BDNF trial implanted approximately the same number of devices. Catheter complication rates varied from 5% to 56%, indicating that the complication rate was not related simply to the number of implantation procedures that each surgeon performed. Center numbers on the horizontal axis are arbitrary.

Preoperative Examination

In addition to physical and neurologic examinations to assess a patient's pain disorder or spasticity, physicians should examine candidates for implantation of an intrathecal drug administration system with pump and catheter placement in mind. Noteworthy items include spinal deformities; previous spinal surgery, including fusion and/or instrumentation; abdominal surgery, including existing or expected

ostomies; and any unusual features of body habitus, such as obesity or emaciation. A review of existing spinal radiographs is useful, especially when spinal instrumentation is present. However, the use of intraoperative fluoroscopy makes special preoperative X-ray films unnecessary in most routine cases.

Antibiotic Prophylaxis

Patients should receive parenteral perioperative antibiotic prophylaxis similar to that used for the implantation of CSF shunt devices (7–9). The antibiotic regimen should be based upon the experience and preference of the implanting physician, taking into account institutional variations in the antibiotic sensitivity of bacteria most commonly associated with postoperative infections. For routine cases, a single dose of an agent effective against gram-positive skin flora should be administered within the hour before skin incision. More potent, or later-generation antibiotics should be reserved for unusual or special cases (eg, drug hypersensitivity or previous infection with resistant organisms). Available evidence does not support the administration of additional postoperative doses of antibiotics (7).

Preoperative Planning of Pump Position

The pump can be placed on the right or left side of the abdomen, depending on the patient's and physician's preferences. Specific factors that may influence selection of the pump pocket location include: the patient's handedness (some patients prefer to have the pump on the nondominant side); automobile seatbelt use, which depends upon country of residence and whether the patient is most often a driver or passenger; wheelchair use; occupation; or fashion preferences, such as form-fitting clothing or belt location. In any case, one should plan pump placement to avoid impingement upon the rib cage or iliac crest. Catheter access ports should be oriented uniformly, either at 3, 9 or 12 o'clock when facing the patient, in order to facilitate refill procedures. For obese patients, especially those with a large panniculus, one should mark the pump position preoperatively with the patient in the standing position, because abdominal tissues can change position significantly when the patient is placed in the lateral decubitus position during surgery.

Skin Preparation and Operating Room Personnel

A full surgical scrub and skin preparation with a commercial antiseptic cleanser and solution is recommended. Sterile draping with the addition of an occlusive, adhesive, antiseptic drape also is recommended. Because implant procedures involve operating on the patient's front and back sides, a two-person surgical team may work more efficiently and may shorten the procedure. But, reducing personnel traffic in the operating room also is desirable (10) because as many as seven individuals may be present at one time: surgeon, surgical assistant or resident, scrub nurse or technician, circulating nurse, anesthesiologist, nurse anesthetist or anesthesiology resident, and a radiology or fluoroscopy technician. A physician operating alone may wish to insert the intrathecal catheter before fashioning the pump pocket because most surgical problems involve placement of the catheter, not creation of the pump pocket. Creating the pocket first, followed by inability to insert the catheter, could leave the patient with an empty subcutaneous pocket.

Catheter and Pump Design

The authors were evenly divided in their individual preferences for one-piece vs. two-piece intrathecal catheters. However, two-piece catheters lend themselves to a more robust anchoring technique by allowing an anchoring suture to be tied securely around the metal connector without risk of occluding the catheter. In addition, it is not possible to pull a catheter through the metal pin of a two-piece connector. Consensus panel members uniformly recommend the use of pump models having a catheter access port to facilitate evaluation of pump and catheter function in the event of a suspected postoperative malfunction. Preparation of the pump for implantation includes the steps of warming, purging, and filling according to manufacturers' recommendations.

Catheter Insertion Level

The authors recommend inserting the catheter at the L2-3 or L3-4 level, unless the patient's anatomy, disease process, previous surgery, or other unusual

circumstances dictate otherwise. Insertion of the catheter above L-2 may risk injury to the *conus medullaris*. One also should avoid catheter entry at the more mobile, lower lumbar segments: L4-5 or L5-S1. Although no formal studies have been performed to confirm this hypothesis, anecdotal evidence and the authors' experience suggest that catheter kinks, breaks, and/or dislodgement from the intrathecal space occur more frequently with catheters inserted below the L3-4 level.

Tuohy Needle Insertion Technique

Passage of the Tuohy needle for catheter insertion into the spinal subarachnoid space may be performed percutaneously (before making the skin incision) or after making an incision to expose the supraspinous ligament and lumbo-dorsal fascia. If one elects to pass the needle before creating the skin incision, the needle must be left in place until all sharp dissection for the incision is complete. Although a monopolar cautery or cutting-cautery instrument is useful for dissection around the silicone catheter, anchors, and connectors, that instrument should not be used when the spinal needle is in the surgical field. With either needle insertion procedure, the length of the incision should be proportional to the patient's body habitus, and should be long enough to assure unequivocal identification of and adequate surgical access to the lumbo-dorsal fascia.

The authors recommend use of a shallow-angle, paramedian oblique needle insertion angle and trajectory (Fig. 3A,B). The entry point of the needle into the skin (or fascia, if needle insertion is performed through an open incision) should be approximately 1–1½ vertebral levels below the interlaminar space selected for dural puncture and 2 cm lateral to the midline, on the side of the intended pump pocket. The rationale for the paramedian approach ipsilateral to pocket placement is to avoid having the catheter cross the spine. Under fluoroscopic monitoring in the true, anatomic, cross-table, anterior-posterior (AP) plane with the patient in the lateral decubitus position, the rostro-caudal needle entry site is 1–1½ levels below the intended intralaminar or dural puncture site; the lateral needle entry coordinate approximately overlies the line of the vertebral pedicles. The imaging target for the needle tip is the midline of the selected interlaminar space. The needle stylet should be kept in place during dural puncture, with the beveled needle tip oriented rostrally when the catheter is inserted.

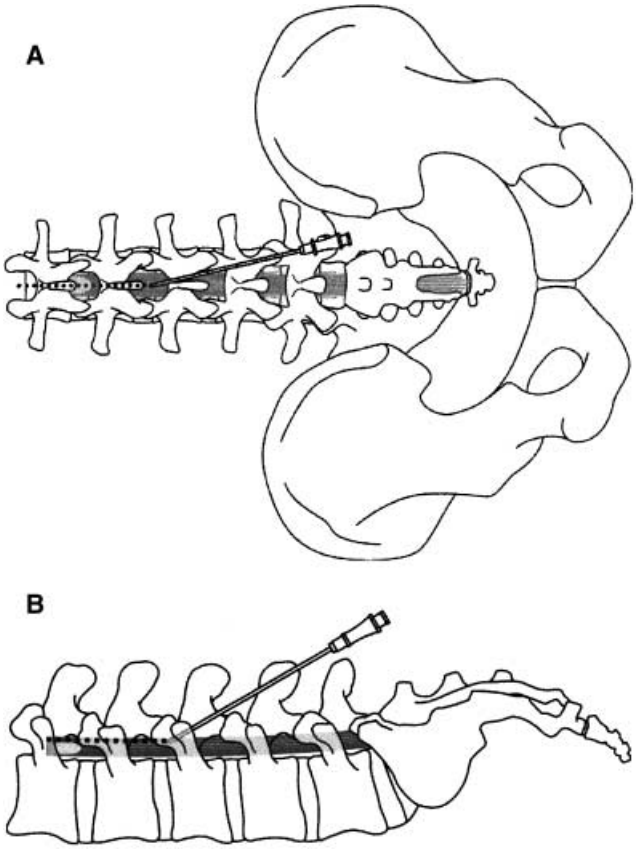

Figure 3. A) Shallow-angle, paramedian oblique needle insertion technique, posterior (dorsal) view. In the anterior-posterior (AP) plane with the patient in the lateral decubitus position, the rostro-caudal needle entry site is 1–1½ levels below the intended intralaminar or dural puncture site; the lateral needle entry coordinate approximately overlies the line of the vertebral pedicles. The target for the needle tip is the midline of the selected interlaminar space. B) Shallow-angle, paramedian oblique needle insertion technique, lateral view. The entry point of the needle into the skin (or fascia) is approximately 1–1½ vertebral levels below the interlaminar space selected for dural puncture and 2 cm lateral to the midline, on the side of the intended pump pocket.

A return of CSF through the needle, which may occur even with the stylet in place, signals entry into the subarachnoid space. If little or no CSF returns through the needle after dural puncture, the operating table may be adjusted into reverse Trendelenburg position to promote CSF accumulation in the lumbar thecal sac. Gentle aspiration also

is permissible. The stylet should be exchanged swiftly for the intrathecal catheter, in order to avoid collapse of the dural sac, and to minimize the risk of postoperative headache from excessive CSF loss. If the catheter must be withdrawn, even partially, during positioning, it should not be withdrawn through the Tuohy needle. That action can cause the sharp needle to weaken, nick, or sever the catheter. In difficult cases, or to assure catheter location within the subarachnoid space, one may inject a small volume of water-soluble, nonionic contrast medium through the catheter. Only low osmolar contrast media approved for intrathecal use (myelography) should be used. Intrathecal administration of unapproved ionic contrast media may cause serious adverse effects that can include seizures, neurologic injury, and death (11).

Some physicians place a purse-string suture through the lumbo-dorsal fascia and around the catheter in order to reduce the likelihood of CSF leakage, subcutaneous CSF collection, and/or postoperative headache (12). The purse-string suture should be placed before removing the Tuohy needle. The suture can be tightened gently around the catheter after needle removal, taking care not to occlude or kink the catheter.

The recommended shallow entry angle offers several advantages over other approaches. It may facilitate rostral passage of the catheter within the intrathecal space, and may help stabilize the catheter against dislodgement from the spinal canal by virtue of catheter passage though soft tissue for 1–1½ spinal segments before intralaminar or dural puncture. In contrast, postmarket surveillance data suggest that the conventional, midline, lumbar puncture-like catheter insertion technique is associated with an approximately 20% complication rate (8703 W, 8709, and BDNF trials). Midline implant technique-related complications include: intradural catheter fractures as a consequence of the acute bend at the needle tip, catheter fracture at the level of the fascia due to friction or pressure from the tips of the spinous processes, and kinks at or near connector hardware where the catheter makes a right-angle or compound bend.

Catheter Placement and Stylet Removal

Insertion of the catheter under fluoroscopic guidance helps to assure that the tip is positioned at the desired level. Implanters should make certain that the catheter guide wire is seated completely, with its hub against the proximal end of the catheter. The guide wire should remain in place during all maneuvers to insert or position the catheter. Fluoroscopic monitoring of the catheter's position during removal of its flexible stylet can prevent dislodgement during this step of the procedure. Due to the relatively high coefficient of friction between a long, one-piece catheter and its internal stylet, take special care not to damage such a catheter during the process of stylet removal. To avoid shearing off the catheter tip from collapsing it lengthwise (like an accordion bellows) against the sharp edge of the needle, remove the Tuohy needle from the spinal canal first, hold the catheter gently at its site of entry into the fascia, and then slowly remove the stylet.

If the catheter cannot be advanced easily in the intrathecal space, most authors recommend that the catheter and needle be removed (remove the needle first to avoid shearing the catheter at the needle tip) and re-inserted with a slightly different trajectory. Although a majority of the authors advise that attempting to steer or manipulate the catheter after removing the needle usually is unsuccessful, one (MST) performs this maneuver routinely without difficulty. If the catheter cannot be advanced, he prefers making the incision, removing the needle, and attempting to steer the catheter rather than withdrawing the needle and catheter and inserting the needle again. Additional punctures increase the chance of postoperative CSF leaks and associated symptoms. Return of CSF from the open end of the catheter confirms that the tip is within the CSF and that the catheter is not occluded.

Catheter Anchoring

Various catheter anchoring techniques can reduce the likelihood of dislodgement and other complications. Follett and Naumann found that six of 10 catheter dislodgments occurred when the anchoring step was omitted (5). The omission of catheter anchoring or other steps of the implantation procedure may shorten surgery by a few minutes, but may cause the patient to experience delayed postoperative complications that require even more time to correct. Available catheter anchors include elbow, butterfly, and V-wing-shaped devices. In

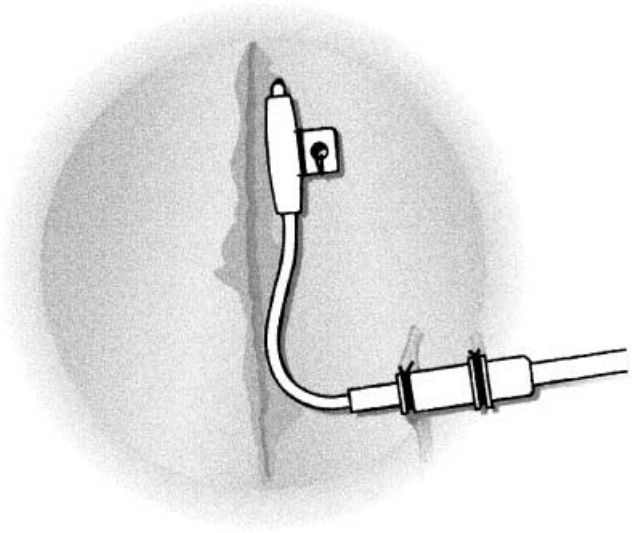

Figure 4. Detailed view of the two-piece catheter anchors. This intraoperative view of the surgical incision illustrates placement of the V-wing and two-piece catheter connector anchors.

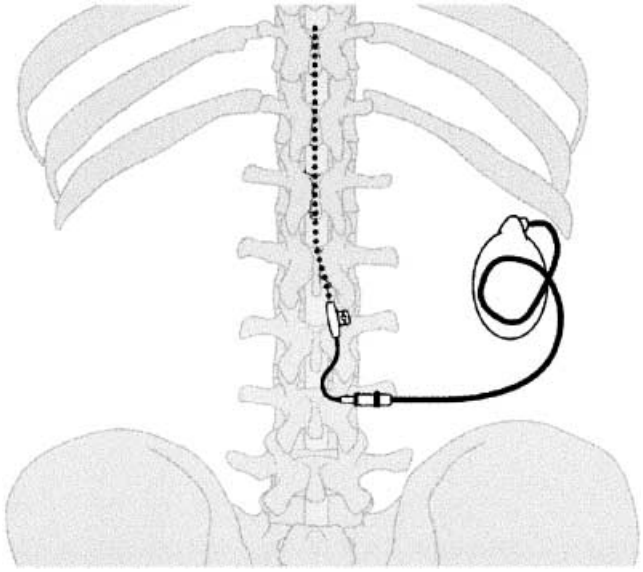

Figure 5. Transparent overview of the two-piece catheter, anchors, and drug delivery pump. The recommended drug administration system implantation procedure minimizes tensile forces at the catheter-entry site, uses gentle curves and smooth transitions to prevent kinks or breakage, anchors the catheter securely to the lumbo-dorsal fascia, and minimizes traction on the intraspinal catheter segment by placing loops of excess catheter material beneath the pump within its pocket in the ventral abdominal wall.

addition, the most robust method involves use of the two-piece catheter connector as a fascial anchor (Fig. 4). The authors believe that it is critical to anchor the catheter to the lumbo-dorsal fascia, not to the subcutaneous fat. Heavy, nonabsorbable suture material should be used for this application in all cases.

The goals and functions of the various anchoring techniques or devices are to secure the catheter against dislodgement while preventing tension or angulation caused by patient motion, either transmitted from the pump or caused by the anchoring device or by the procedure itself. Another important requirement is that the anchor not occlude the catheter lumen. In patients being implanted with a two-piece catheter, a V-wing-shaped anchor near the fascia entry point can help to prevent catheter dislodgement from the intrathecal space. Then the proximal-to-distal catheter connector can be used as an additional fascia anchor. Another important point when using two-piece catheters is to trim the distal (intraspinal) catheter segment in a manner that leaves adequate slack between its fascia entry/anchor point and the proximal-to-distal connector, which also should be anchored to the lumbo-dorsal fascia.

Common principles of the recommended anchoring technique include prevention of tensile forces at the catheter entry site, gentle curves or loops to prevent catheter kinks or stress-induced breakage against the anchor device, and secure tying of the catheter to the anchor and of the anchor to the fascia in an orientation that enhances the antitensile and antikink properties (Figs 4 and 5). Secure catheter connections and secure catheter anchoring to the lumbo-dorsal fascia should prevent dislodgment from the spinal canal, which is one of the most common causes of drug administration system failure.

Catheter Tunnel, Connections in the Pump Pocket, and Wound Closure

The catheter should be passed from the smaller spinal incision to the larger pump pocket within the abdominal wall by using a hollow, one-piece tunneling tool or a solid-rod tunneling device. The pocket should be of sufficient size that the incision does not overlie the pump after wound closure. The proximal catheter segment (that attaches to the pump) should be long enough for one or more loops of catheter to be placed behind the pump.

Visual inspection for CSF flow from the end of the catheter (spontaneously or by gentle aspiration) confirms that the catheter is patent and that the tip is still within the thecal sac. Be certain to use the proper pump-catheter connector to secure the catheter to the pump. Connections between the catheter and pump must be tied with heavy, nonabsorbable suture material according to the manufacturers' instructions.

Optimally, the pump should rest on the external oblique fascia or anterior layer of the rectus sheath at a depth of 1 cm to 2 cm below the skin, with the refill and catheter access ports facing outward from the patient's body. Deeper placement may complicate pump refill procedures by making the reservoir access port difficult to locate by palpation.

However, in slender patients, the pump may be implanted under the muscle fascia, which lowers its profile and provides a more secure wound closure. In order to prevent migration or inversion, the pump must be secured to the underlying tissue in at least three places, also using heavy, nonabsorbable suture. Failure to do so can allow the pump to flip over within the pocket. That event causes the reservoir access port to face toward the patient's body, rendering the pump impossible to refill. The nipple or outlet of the pump that attaches to the catheter should *not* be sutured down. Securing the pump within the pocket is the last opportunity to make certain that neither the pump, nor its protruding access port, impinges upon the ribs or iliac crest. Placing the coils of excess catheter behind the pump avoids damage by needles during refill or catheter access port procedures. The extra tubing also functions as a strain-relief buffer, preventing motion of the abdominal wall from being transmitted to the spinal catheter segment (Fig. 5). Aspirate CSF through the side port of the pump (if a side port is present) as a final confirmation of catheter patency before closure of the incision.

Copious irrigation of the spinal and abdominal wounds is followed by closure in at least two layers. The deep layer(s) should employ inverted, interrupted, absorbable sutures. Meticulous skin closure is essential to prevent infection or dehiscence (12). Interrupted monofilament skin sutures are standard, although staples may be used if the deep suture layer results in good approximation of the skin edges.

Postoperative Documentation

Most C-arm fluoroscopy units can produce a film to document the vertebral level of catheter entry and of the catheter tip. That information should also be dictated into the operative notes. Other important documentation includes the pump model and serial numbers, the catheter model and lot numbers, the length of the implanted catheter, and the calculated volume of the implanted catheter. To avoid confusion during future troubleshooting procedures, the authors recommend using only metric system units for the catheter length measurements and volume calculations.

SUMMARY AND CONCLUSIONS

The authors conclude that the most common catheter-related complications are a consequence of suboptimal implantation techniques. They believe that eliminating the potential problems inherent in each step of the implantation procedure ought to reduce the overall complication rate substantially. While written communications like the present article are an important source of information for clinicians, such materials are not a substitute for intensive, hands-on professional training. On the device side, manufacturers should produce drug administration pumps, catheters, and accessories that are reliable, easy to use, and accompanied by user-friendly educational and technical materials. The authors are optimistic that patients implanted with well-designed drug administration systems using optimal surgical techniques can expect reliable device performance for many years.

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