Epidural Catheter Reconnection

Safe and Unsafe Practice

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Background: An in vitro model of epidural catheter contamination was used to determine if disconnected catheters can be safely reconnected.

Methods: Epidural catheters were filled with brain–heart infusion (BHI) broth or preservative-free saline containing 5 µg/ml fentanyl. Escherichia coli, Pseudomonas aeruginosa, or Staphylococcus aureus (1 × 10⁶ colony-forming units) was injected into the initial 1.1 ± 0.24 inch (2.75 ± 0.60 cm) of the catheters. To study the effect of bacteria settling in a vertically oriented catheter on the advancement of bacteria along the catheter, bacteria were incubated with catheters in the vertical and the horizontal positions. To determine if bacteria are swept further into a catheter when fluid in it is displaced, catheters were inclined 30 degrees and the fluid in them was allowed to drain from the distal end to various extents. Bacteria were incubated with the catheter held horizontally. After incubation, the catheters were serially sectioned, and the resulting segments were cultured with buffered saline-containing gelatin (BSG), which was collected on BHI agar plates for colony counts. This determined if a segment of the catheter remained internally sterile distal to the point of disconnection. Effectiveness of decontaminating the exterior of the catheter was also tested as follows: Catheters (n = 10) were first immersed in BSG containing 1 × 10⁶ S. aureus, immediately immersed in betadine for 2 min, exposed to air for 3 min, cut with a sterile instrument, and reconnected to a sterile screw cap catheter connector. Reconnected catheters were perfused with 10 ml BSG for 1 hr. Collected perfusate (100 µl) was removed for direct colony count; the remaining perfusate was mixed with an equal volume of BHI and incubated overnight. A 100-µl aliquot of BHI–BSG mixture was sampled the next day. No bacteria were cultured from either the perfusate or BHI–BSG mixture.

Results: Eight hours after contamination, as long as the fluid in the catheter was static, no bacteria were detected more than 13 inches (32.5 cm) from the contaminated end of catheters filled with BHI and no more than 8 inches (20 cm) from the end of those filled with fentanyl solution. This finding was not affected by incubation of the catheter in the vertical position. Fluid displacement less than 8 inches (20 cm) had no effect on dissemination, but when fluid was displaced 13 inches (32.5 cm), bacteria were found at the end of the catheter, 35 inches (87.5 cm) away. No bacteria were recovered from the perfusate of reconnected catheters after the catheters were cleaned with betadine and cut with a sterile instrument.

Conclusions: There may be an area distal to the disconnected end of an epidural catheter where its interior remains sterile for at least 8 hr. Such an area exists only when the fluid in the catheter remains static. Furthermore, the exterior of the catheter can be adequately cleaned to prevent bacteria from entering the catheter when reconnected at that point. (Key words: Anesthetic techniques: epidural. Complications: infection. Equipment: catheters, epidural; disconnections; sterilization. Infection. Monitoring. Pain: acute, service.)

EPIDURAL catheters have been used traditionally in the operating room and labor and delivery suites, where both the catheter and the patient are closely monitored. Now epidural techniques are used increasingly to control acute pain for several days after operation in less intensely monitored settings. Recent studies reporting improved outcome after lower extremity revascularization in patients who then received epidural opioids, local anesthetics, or both may stimulate further interest in this technique in this population of patients.¹,² In these new applications, the catheter may remain in place for prolonged periods in patients who are ambulatory, which may increase the chance that an epidural catheter may become disconnected from its leur lock infusion port. Furthermore, outside of the operating room, the time between catheter disconnection and its discovery may be several hours rather than minutes. Because there is no way to know if the catheter tip has been contaminated after an unwitnessed disconnection, contamination must be assumed.

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When a catheter becomes disconnected, only two alternatives exist: The catheter may be removed or reconnected. Removal deprives the patient of the benefits of the therapy or engenders the risk associated with reinsertion. In patients treated with anticoagulants, removal or reinsertion may also increase the potential for hematoma. Recconnection, on the other hand, incurs the risk of introducing microorganisms to the epidural space unless the sterility of the system can be ensured. The potential for contamination in the event of reconnection has been demonstrated.  

Staphylococcus is the most common cause of epidural abscesses, although other bacteria also may be responsible. Although cleaning reduced the variety of bacteria on the exterior of the catheter in one study, Staphylococcus species could not be eliminated. That study did not address contamination of the interior of the catheter or the influence of catheter reconnection on internal contamination.

The only way to ensure that reconnecting a catheter will not lead to infection is to exclude bacteria completely from the inside of the catheter. This assurance requires two conditions. First, bacteria must not advance from the disconnected (contaminated) end past the point of reconnection. Second, the method of reconnection must avoid contaminating the interior of the catheter. Simply cutting through a catheter could transfer bacteria from the contaminated exterior to the sterile interior because the exterior remains contaminated even after thorough cleaning.

Because the patent end of an epidural catheter must be considered contaminated when it becomes disconnected, we developed an in vitro model of epidural catheter contamination to determine how far bacteria advance along the interior of the catheter and if an area of catheter could be cleaned well enough to be reconnected. Bacteria might be swept further into a catheter if fluid that became contaminated near its disconnected end then flowed into the patient. To address this, we evaluated how often fluid is displaced into the epidural space through a disconnected in-dwelling catheter. We also tried to determine if fluid displacement in the catheter contributes to advancement of bacteria. Finally, we developed and tested a technique for cleaning a disconnected catheter before reconnecting it.

Methods

Eighteen-gauge catheters (product CE-18TB; Burron Accu-bloc Epidural Catheters, Bethlehem, PA) were removed from their packages under strict sterile technique and secured (n = 24 in groups of six) to a 75 × 100 cm sterile glass plate with steristrips. The steristrips were arranged in parallel pairs at 5-inch (12.5-cm) intervals along the length of the catheter such that each catheter could be cut between the strips at 5-inch (12.5-cm) intervals while the ends remained fixed to the glass plate. Three inches (7.5 cm) of the proximal end of the catheters (end fitted with a luer lock) extended beyond the edge of the glass plate but remained within a sterile field. The luer lock connector was fitted to this end of the catheter in the standard manner, which allowed us to close this end of the catheter with a multiport manifold. The distal end (patient end) of the catheter was cut with a sterile scalpel, which eliminated the side holes. Two inches (5 cm) of the catheter at its distal end extended beyond the edge of the glass plate. A second luer lock adapter was fitted on the distal end and closed with a stopcock. The resulting length of the catheter was approximately 35 inches (87.5 cm).

Multiport manifolds were arranged in series and the luer lock adapters were attached to the individual ports using sterile, double-male adapters. The first and last stopcocks in the manifold were closed, which scaled the system. Another sterile glass plate was then placed on top of the catheters and a sterile adhesive iodoform drape was wrapped around the glass plates to provide a closed, sterile system in which the interior of the catheter was effectively isolated from the exterior.

Catheters were filled with either brain–heart infusion (BHI) broth (n = 18) to provide optimal growth conditions for bacteria or preservative-free (0.9%) saline containing 5 μg/ml fentanyl (n = 6) to simulate clinical conditions. Growth conditions provided by BHI ensured maximal propagation of bacteria. Three species of bacteria were tested: Staphylococcus aureus and Escherichia coli (gram positive and gram negative) were used because they are likely to contaminate a lumbar epidural catheter. In addition, S. aureus might be most resistant to sterilization or at least be most difficult to eradicate and is the most frequently implicated organism isolated from in-dwelling catheters. Pseudomonas aeruginosa was used because it frequently occurs in very ill patients, is motile, and is surrounded by a slime capsule, which could change adherence characteristics of the bacteria and its ability to exist in an adverse environment.

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1 Slime capsule is a term used in microbiology for a layer of mucus that surrounds an organism. The slime capsule of Staphylococcus is composed of polysaccharides.

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Epidural Catheter Disconnection

Eighteen catheters were filled with BHI and six were filled with a solution of fentanyl in preservative-free saline. Each of the 18 catheters filled with BHI were inoculated with approximately $1 \times 10^5$ colony-forming units (CFU) of one of the three bacteria ($n = 6$ each) in a 5-$\mu$l volume. A micropipette system was used to ensure that bacteria did not contaminate the external surface. Before testing for bacterial advancement within the catheter, we determined that the length of catheter that would be filled by the 5-$\mu$l volume of inoculum was $1.1 \pm 0.24$ inches ($2.75 \pm 0.60$ cm).# Five of the six catheters filled with fentanyl solution were similarly inoculated ($S. aureus$, $n = 2$; $E. coli$, $n = 2$; $P. aeruginosa$, $n = 1$). The remaining fentanyl-filled catheter was not inoculated and served as a control. All 24 catheters (18 filled with BHI and six filled with fentanyl solution) were incubated at 40°C in the dark for 8 hr to promote maximal propagation of bacteria. These studies were repeated with 24 hr of incubation for $E. coli$ and $S. aureus$.

After incubation, the extent of bacterial advancement along each catheter was determined by serially sectioning the catheters into 5-inch (12.5-cm) segments between the steristrips beginning from the distal end. Strict sterile technique was maintained to avoid extraneous contamination. A separate blade was used for each catheter to avoid cross-contamination. Each catheter segment was then eluted retrograde with 0.1 ml (approximately four catheter volumes) buffered saline containing gelatin (BSG). The eluate (0.12 ml)* was collected on a BHI agar plate, spread evenly across the plate, and incubated. The number of CFUs recovered from each segment was counted.

Two mechanisms by which bacteria can advance within a catheter were tested:

- **Settling of bacteria in vertical catheters:** The protocol was repeated with BHI ($n = 6$) and fentanyl solution ($n = 6$) with catheters vertical during the 8-hr incubation.
- **Fluid displacement:** This protocol was designed to simulate the clinical situation in which fluid drains into the epidural space by gravity when a catheter becomes disconnected. Four series of five catheters filled with a solution of fentanyl (5 $\mu$g/ml) in preservative-free (0.9%) saline were inoculated with approximately $1 \times 10^5$ CFU/5 $\mu$l of $S. aureus$. The distal ends of the catheters were sealed using a sterile three-way stopcock, as previously described. Catheters were placed at a 30-degree incline, and the stopcock opened to allow fluid to flow through the catheter and drain out through the stopcock. Fluid displacement was confirmed and monitored by observing the position of the air-fluid interface, or meniscus, within the catheter. The meniscus was allowed to advance 1, 2, 8, or 13 inches (2.5, 5, 20, or 32.5 cm), at which point the stopcock was closed. The catheters were returned to the horizontal position and incubated at 40°C for about 8 hr. After incubation, catheters were serially sectioned into 5-inch (12.5-cm) segments, and CFUs were determined for each segment and compared with those obtained from the static system.

To study the risk of internal contamination from reconnection, ten catheters were filled with BSG and a segment of the catheter was immersed in a suspension of $1 \times 10^5$ CFU/ml $S. aureus$ for 5 min. The contaminated segment of the catheters was immersed immediately in betadine solution for 2 min. The catheters were removed from the betadine and exposed to room air for 3 min. Catheters were cut in the center of the treated area with a sterile blade and the distal end was reconnected to a sterile luer lock adapter. Catheters were perfused with BSG at 10 ml/hr for 1 hr. The entire volume of perfusate was collected, and 100 $\mu$l was spread onto BHI agar plates for direct colony count. The rest of the perfusate (9.9 ml) was combined with an equal volume of BHI broth and incubated overnight (40°C) to increase the sensitivity of the assay by promoting bacterial growth. The next day, a 100-$\mu$l aliquot of this perfusate-BHI mixture was plated and the CFUs were counted 24 hr later.

After obtaining approval from the institutional review board, we studied fluid displacement in indwelling catheters in 30 consecutive patients. The study was restricted to patients receiving care for acute pain with a continuous epidural infusion at $\geq 10$ ml/hr for at least 12 hr. The epidural infusion was discontinued for 1 hr. Exactly 1 hr later, the patient was placed in the lateral decubitus position and the catheter was aseptically disconnected from the luer lock adapter. The catheter was extended vertically (perpendicular to the long axis of the patient) and the fluid was allowed to drain passively into the epidural space by gravity. Fluid displace-

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#With a micropipette system, 5 $\mu$l of buffered saline containing glucose was injected into six catheter segments, and the linear distance occupied by the saline was measured. Each catheter was filled three times to allow for intra- and intercatheter variation.

**100 $\mu$l delivered + 20 $\mu$l dead space in the segment.**

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Table 1. Effect of Different Media on Bacterial Propagation during 8 h of Incubation in an In Vitro Model of Catheter Contamination

<table>
<thead>
<tr>
<th>Bacteria Cultured from Segments of Contaminated Catheters (count*)</th>
<th>Bacteria</th>
<th>1–8 in. (2.5–20.0 cm)</th>
<th>8–13 in. (20–32.5 cm)</th>
<th>13–35 in. (32.5–87.5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline solution</td>
<td>None (control) (n = 1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Saline solution</td>
<td>S. aureus (n = 2)</td>
<td>&gt;10^7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Saline solution</td>
<td>E. coli (n = 2)</td>
<td>&gt;10^7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Saline solution</td>
<td>P. aeruginosa (n = 1)</td>
<td>&gt;10^7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brain–heart infusion</td>
<td>S. aureus (n = 6)</td>
<td>&gt;10^7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brain–heart infusion</td>
<td>E. coli (n = 6)</td>
<td>&gt;10^7</td>
<td>&gt;10^7</td>
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<td>&gt;10^7</td>
<td>0</td>
</tr>
</tbody>
</table>

Each combination of organism, medium, and catheter length produced the same results in all catheters tested with that combination. Brain–heart infusion solution represented an optimal growth condition.

* Count of colony forming units.

ment was considered to have ceased when the meniscus moved fewer than 0.5 inches (1.3 cm) in 2 min. At that time, we determined the length of fluid displacement by measuring the distance from the meniscus to the disconnected end of the catheter. These data are reported as means ± SD.

Results

The first segment of the catheters where the bacteria were injected (initial 8 inches [20 cm]) was contaminated in every case, as expected. All three bacterial species advanced progressively along the catheter (Table 1). After 8 h of incubation in fentanyl solution, the contaminated segment did not differ for motile (E. coli and P. aeruginosa) or immotile (S. aureus) bacteria. We found a difference with BHI: E. coli and P. aeruginosa (motile gram-negative bacteria) both advanced as much as 13 inches (32.5 cm) from the contaminated end, whereas S. aureus remained restricted to the first 8 inches (20 cm) of catheter, regardless of the solution in the catheter. When the incubation period was extended to 24 h, we detected E. coli and P. aeruginosa in every segment along the entire length of the catheters filled with BHI (about 35 inches [87.5 cm]), whereas S. aureus still remained within the first 8 inches (20 cm) of the catheter.

Settling of bacteria in vertical catheters did not contribute to the advancement of bacteria: We did not find bacteria more distant from the contaminated end in vertically than in horizontally incubated catheters. Fluid displacement did contribute to the advancement of bacteria (Table 2): Displacement of 13 inches (32.5 cm) propelled bacteria to the end of the catheter. With displacement of ≥8 inches (20 cm), bacteria were sometimes not recovered from the most proximal segments, which should have been contaminated. These most proximal segments were dry, however. No bacteria were recovered from any of the ten reconnected catheters.

When in-dwelling catheters were extended vertically, fluid entered the epidural space of 18 of 30 patients, which resulted in fluid displacement of 22 ± 8 inches (55 ± 20 cm).

Discussion

Our recommendations and comments on the clinical implications of our results are deliberately conservative to ensure maximal patient safety. Two conditions are necessary for safe reconnection of disconnected catheters: a point of internal sterility and adequate cleaning to prevent entrance of bacteria on reconnection. We used an in vitro model to determine if these two conditions can actually be satisfied. In the model, we injected bacteria into the first 1.1 ± 0.2 inches (2.75 ± 0.6 cm) of the catheter instead of depending on passive movement of bacteria into the catheter. Although this may at first seem not to resemble clinical circumstances, we were not interested in determining whether bacteria entered the catheter: If a catheter is disconnected, the proximal portion must be considered contaminated. Rather we sought to determine if a point of sterility could be assured once contamination (disconnection) had occurred. Our methods ensured contamination. Furthermore, if the disconnected end of the catheter were lying in a puddle of inoculate above the level of its distal end, contaminant could enter the epidural catheter by capillary action or by a siphon effect. The present study showed that, even when bacteria were injected directly into the catheter, the interior of the catheter remained sterile more than 8 inches (20 cm) distal to the inoculated end for 8 h when fluid in the catheter was static. Therefore, when the fluid column is static, the catheter can be reconnected at any point along the catheter distal to 8 inches (20 cm) from the disconnected end if it is done in a manner that precludes bacteria from being introduced in the process.
Table 2. Effect of Fluid Displacement, as Judged from Meniscus Movement, on Dissemination of S. aureus in an In Vitro Model of Catheter Contamination

<table>
<thead>
<tr>
<th>Fluid Displacement in the Catheter (in. [cm])</th>
<th>Bacterial Dissemination† from the Contaminated End of the Catheter (count‡)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0–8 in. (0–20.0 cm)</td>
</tr>
<tr>
<td>1 (2.5) (n = 10)</td>
<td>$10^2$</td>
</tr>
<tr>
<td>2 (5.0) (n = 5)</td>
<td>$10^3$</td>
</tr>
<tr>
<td>8 (20.0) (n = 5)</td>
<td>$10^4$</td>
</tr>
<tr>
<td>13 (32.5) (n = 5)</td>
<td>$10^4$</td>
</tr>
<tr>
<td>Catheter 1</td>
<td>0§</td>
</tr>
<tr>
<td>Catheter 2</td>
<td>0§</td>
</tr>
<tr>
<td>Catheter 3</td>
<td>0§</td>
</tr>
<tr>
<td>Catheter 4</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Catheter 5</td>
<td>$10^4$</td>
</tr>
</tbody>
</table>

* For 1 (2.5 cm) to 8 (20 cm) inches of fluid displacement, the results were the same for all tests. For fluid displacement >13 inches (32.5 cm), dissemination varied among catheters; therefore, results are presented for each catheter.
† Bacterial dissemination manifested as presence of bacteria throughout the contaminated area.
‡ Count of colony forming units; $10^3$ and $10^4$ are visual estimates.
§ Bacterial counts were most likely significantly reduced in this segment because fluid displacement left the segment dry and desiccation killed bacteria.

Safe reconnection, however, also requires a protocol that maintains internal sterility by preventing any bacteria from entering the catheter during its reconnection. Although the variety of bacteria on the exterior of a catheter can be reduced by cleaning, S. aureus cannot be eliminated reliably.4 The exterior of any indwelling epidural catheter is invariably contaminated and impossible to sterilize. Thus a clear potential for contamination exists if catheters are reconnected. Soaking highly contaminated catheters in betadine for 2 min and airing them for 3 min precluded bacteria from entering the catheter in ten of ten trials, when catheters were cut with a sterile blade and reconnected.

In more than two thirds of patients, fluid drained into the epidural space by gravity less than 1 hr after discontinuation of an epidural infusion when the catheter was disconnected. A meniscus within the catheter is evidence that fluid in the catheter has drained into the epidural space. Although it may seem intuitively correct that the total distance bacteria advance should equal the sum of the linear distance they advance in a static system plus the linear distance they are carried by fluid displacement, this is not the case. For reasons that are not understood, our data show that, when linear displacement was 13 inches (20 cm), bacteria reached segments of the catheter far beyond the initial site of contamination and far beyond what would be logically and empirically predicted. Often bacteria were disseminated to the end of the catheter, more than 35 inches (87.5 cm) from the point of inoculation (disconnection). Thus bacteria can advance rapidly when fluid is displaced. As a result, when the fluid column is not static, the risk of contaminating the epidural space is greatly increased in the event of a disconnection, and disconnected catheters are best removed, except when the duration of the disconnection and the linear fluid displacement are very limited; that is, when disconnection is observed or detected shortly after it occurs. This would probably be the case in the operating room or in the labor and delivery suite. In other hospital settings, however, the duration of a disconnection may not be known. When unwitnessed disconnection occurs, and the meniscus is more than 10 inches (25 cm) from the free end of the catheter, the catheter should be removed as soon as possible.

Our results suggest that an area of absolute internal sterility can be predicted in a catheter when the fluid has remained relatively static. This is true even in the worst conceivable clinical circumstances in which a large quantity of bacteria is deposited directly into a catheter filled with growth media and incubated under optimal conditions. Even in these circumstances, however, safe reconnection (that is, reconnection that ensures absolute sterility of the interior of the catheter) is possible, but only if the fluid is static.

When the fluid in a catheter is static and disconnection has occurred within 8 hr, the proximal end of the catheter can be cut away and the distal end reattached in a manner that prevents bacteria from entering the catheter in the process. The reconnection tech-
nique must prevent all bacteria from entering the interior of the catheter. Statistical analysis demonstrating significant reduction would be irrelevant; the interior of the catheter must be sterile to be safely reconnected. Data from the present study suggest that catheters may be reconnected safely if the catheter is cleaned and reconnected according to the technique described herein. With this technique, the interiors of none of the ten reconnected catheters became contaminated. Contamination with a single bacteria would otherwise have resulted in at least $10^5$ CFU/ml when incubated at 40°C with a 50:50 mixture of BHI:BSG for 24 hr.††

In summary, when a disconnection occurs fewer than 8 hr before reconnection and the fluid has remained relatively static within the catheter, reconnection may be considered if both the following conditions are met: (1) The meniscus is within 5 inches (12.5 cm) of the disconnected end, and (2) fluid does not move within the catheter when it is raised above the level of the patient.‡‡ When these conditions are not satisfied, the catheter should be removed immediately. These conditions probably occur infrequently outside the operating room and labor and delivery suites. When the reconnection conditions are met and it is prudent to leave the catheter in place, or when removing it engenders substantial risk, a segment of the catheter fully 10 inches (25 cm) from the meniscus should be immersed in betadine for 5 min and allowed to dry completely. The catheter should then be cut with a sterile instrument in the center of this area and reconnected to a sterile connector. Although our data show that advancement of bacteria in fentanyl solution is limited to fewer than 5 inches (12.5 cm), our recommendations are deliberately conservative to eliminate any possibility of contaminating the epidural space. Similarly, although the data indicate that it is safe to reconnect a catheter when fluid has moved 8 inches (20 cm) or less, we recommend a more conservative interval to ensure sterility of the interior of the catheter (5 inches [12.5 cm]). Finally, our data show that immersion for 2 min in betadine followed by airing for 3 min prevented contamination of the interior of the catheter on reconnection. We recommend immersion for 3 min followed by complete drying. This takes advantage of the effect of desiccation on bacteria, prolongs the contact between the betadine and the bacteria, and limits the potential for betadine to enter the epidural space and produce arachnoiditis.†† In patients receiving anticoagulants or who, for other reasons, will absolutely require an in-dwelling epidural catheter after operation, a disconnection-resistant catheter should be placed initially.

References


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††Considering the doubling time of bacteria used in our study, under the growth conditions provided, at least 2^5 bacteria would have been present 12 hr after incubation.
‡‡When an epidural catheter is disconnected from an infusion pump, because fluid in it can be displaced into and out of the epidural space, simply knowing the location of the meniscus may not be sufficient. It must also be determined that the fluid has not been displaced further than where the meniscus is located when the disconnection is discovered.