Limited data exist regarding the echogenicity of perineural catheters, but visualization is crucial to ensure accurate placement and efficacy of the subsequent local anesthetic infusion. The objective of this study was to determine the comparative echogenicity of various regional anesthesia catheters. In an in vitro porcine-bovine model, we compared the echogenic qualities of 3 commercially available regional anesthesia catheters and 1 catheter under development to optimize echogenicity. Outcomes included visual echogenicity ranking, image quality, and scanning time, as assessed by 2 blinded investigators. The experimental catheter was found to be more echogenic than 2 of the 3 comparators.

Key Words—continuous peripheral nerve block; echogenicity; musculoskeletal ultrasound; perineural catheter; ultrasound; ultrasound-guided regional anesthesia
Experimental Design
We used an in vitro model consisting of a bovine tendon (to represent a target nerve) placed between the fascial planes of two adjacent muscle groups approximately 4 cm deep in a porcine hind quarter as described previously.15 Three commercially available nerve block catheters (single-orifice 19-gauge stimulating Arrow StimuCath [Teleflex Medical, Research Triangle Park, NC], multi-orifice 19-gauge nonstimulating PeriFix FX [B. Braun Medical, Inc, Bethlehem, PA], and multi-orifice 20-gauge nonstimulating Contiplex [B. Braun Medical, Inc]), and a single-orifice 21-gauge nonstimulating flexible wire-reinforced perineural catheter in development (Ultra-Kath [Epimed International, Inc, Johnstown, NY]), were studied. The perineural catheter in development was based on an existing commercially available spring-reinforced flexible epidural catheter (SPIROL [Epimed International, Inc]), but the twin internal wires are braided to enhance echogenicity (Figure 1).

Each catheter was tested 15 times for a total of 60 trials; the order of catheter insertion procedures was randomly assigned using a computer-generated randomization table (www.randomizer.org). All catheters were inserted through a Touhy-tip placement needle inserted at an angle of 45° to the skin (Figure 2A) by a single investigator (R.D.H.Y.) with expertise in ultrasound-guided perineural catheter placement using a short-axis, in-plane technique1,3,16 with a high-frequency (13–6 MHz) ultrasound transducer (M-Turbo HFL38 [FUJIFILM SonoSite, Inc, Bothell, WA]). The type of examination was set for “nerve” for all scanning procedures, and none of the other settings, including gain, was adjusted after initial machine startup. Each catheter was inserted 4 cm below the surface of the porcine model, and the ultrasound settings were standardized at a depth of 4 cm. The catheter insertion sites and remaining catheter lengths were obscured to ensure that the investigator performing the ultrasound scanning and capture of images (T.E.K.) would remain blinded to the catheter type (Figure 2B). To maintain blinding, all captured and stored images were saved as JPEG files under coded file names with no indication of the catheter type.

Outcomes
The primary outcome was an ordered visual echogenicity ranking (1–4: 1, highest; and 4, lowest). For this outcome, catheters were randomly clustered into 15 sets; each set contained 1 of the 4 catheters, which was then ranked (1–4) accordingly. Secondary outcomes included overall catheter visibility scores (range, 0–10; adapted from Maecken et al; Table 1), scanning time (seconds), estimated catheter length seen (percent), as well as scores for artifacts, shadow, and contrast (range, 0–10; adapted from Maecken et al; Table 1). The scanning time was the time taken by a blinded investigator (T.E.K.) to visualize the catheter tip. The secondary outcomes were assessed with all 15 tests combined. Two investigators (E.R.M. and B.C.), who were unininvolved in catheter placement or scanning and blinded to the catheter type and order, performed all echogenicity rankings, visibility scoring, and estimated catheter length assessments using Windows 7 Photo Viewer (Microsoft Corporation, Redmond, WA). The investigators performing the catheter insertion and scanning did not participate in any subsequent study procedures, echogenicity rankings, or data analysis.

Statistical Analysis
Values are presented as mean ± standard deviation, median (range), and number (percent) as appropriate. Normal distribution was determined by Q-Q plots and the Kolmogorov-Smirnov test. Analyses of normally distributed continuous variables were performed by analysis of variance with post hoc pair-wise comparisons by the least significant difference test; non-normal continuous variables (including the primary outcome measure) were compared by the Kruskal-Wallis test with the Mann-Whitney U test for between-group post hoc comparisons. Categorical variables were compared by the Pearson χ2 test. Two-sided P < .05 was considered statistically significant. To assess the reliability of ranking and echogenicity ratings between the expert raters, we calculated intraclass correlation coefficients (ICCs) using 2-way mixed modeling to assess absolute agreement between the raters. We adopted published standards for interpretation of ICCs17; ICCs greater than 0.75 were considered excellent, and ICCs greater than 0.50 was classified as moderate (SPSS version 21 for Windows [IBM Corporation, Armonk, NY]).

Figure 1. Ultra-Kath: a flexible 21-gauge wire reinforced peripheral nerve block catheter in development, designed to improve echogenicity for ultrasound-guided regional anesthesia.
Results

All catheters were inserted according to the protocol with no missing or incomplete data. There was a statistically significant difference in median (range) echogenicity rankings among the catheters studied (Table 1; \( P = .002 \)). The Epimed Ultra-Kath perineural catheter in development was more echogenic than the Arrow StimuCath \( (P < .001) \) and B. Braun PeriFix FX \( (P = .019) \). The B. Braun Contiplex was more echogenic than the Arrow StimuCath \( (P = .008) \). The Epimed Ultra-Kath was ranked first for echogenicity 14 times (47%) compared to the B. Braun PeriFix FX, which was ranked first 8 times (27%; \( P = .003 \)) and the B. Braun Contiplex, which was ranked first 8 times (27%; \( P = .002 \)). The Arrow StimuCath did not rank first in any assessments. Figure 3 shows representative ultrasound images of the catheters studied.

Catheter visibility, artifact, shadowing, and contrast scores are outlined in Table 1. We observed no statistically significant differences in echogenicity visibility, artifact, shadowing, or contrast scores among the catheters studied. The scanning times and estimated catheter lengths seen were not different among the catheters (Table 2).

The ICC for echogenicity rankings between the raters was 0.882 (95% confidence interval, 0.803–0.930) with a Cronbach \( \alpha \) of .881. The ICC for echogenicity visibility was 0.813 (95% confidence interval, 0.689–0.888) with a Cronbach \( \alpha \) of .815. The ICCs for artifact, shadowing, and contrast scores were 0.547, 0.747, and 0.884, respectively.

Discussion

Results from this in vitro study demonstrate that catheters used for regional anesthesia display a wide range of echogenicity. This porcine-bovine model study indicates that the echogenicity of perineural catheters may be improved with a braided internal wire cord. The new non-stimulating flexible wire-reinforced peripheral nerve block catheter in development may offer advantages over 2 of the 3 commercially available catheters in terms of ultrasound visibility despite the fact that the catheter is a smaller gauge. Among the current commercially available catheters studied, the Arrow StimuCath stimulating perineural catheter was the least echogenic.

Several previous studies have evaluated the echogenicity of needles used for regional anesthesia and other interventional procedures. However, the echogenicity of catheters used in regional anesthesia has not been as rigorously studied to date, and there may be inherent limitations in the direct visualization of catheters inserted using ultrasound guidance. A previously published study by Takatani et al evaluated 6 regional anesthesia catheters using a porcine model similar to ours but without the simulated target nerve; only 1 catheter type was also included in our study. In the study by Takatani et al, catheters primed with a saline solution were placed parallel to the surface of the phantom (0°) or at 30° relative to the phantom surface at a depth of only 1 cm. Our study was designed to compare the relative echogenicity of catheters...
when placed at an angle that was more challenging for visualization (45° relative to the phantom surface) with a surface-to-target depth of 4 cm, similar to many common in vivo peripheral nerves using a previously validated in-plane ultrasound-guided perineural catheter insertion technique that does not use priming.1–3,16,19 The potential advantages or disadvantages of saline priming of catheters in terms of ultrasound visualization have not been previously studied, and the results of the study by Takatani et al11 cannot be applied this study, given the differences in catheter selection and techniques.

Although the B. Braun Contiplex catheter can also be considered echogenic according to this study, the rigid catheter design is not ideal for the validated short-axis, in-plane, ultrasound-guided perineural catheter insertion technique.20 When using this technique, a flexible epidural-type catheter is recommended, since it is less likely to overshoot the target nerve20 and may permit insertion of a greater length of the catheter to decrease the likelihood of dislodgement without displacing the tip?; however, the flexible catheter does not routinely remain within the ultrasound plane, making it difficult to visualize during placement. This factor may explain why gains in echogenicity with the flexible catheters did not translate into a greater percentage of catheter length visualized in this study. Alternative techniques, such as long-axis, in-plane, may facilitate catheter visualization but also increase the procedural duration without obvious clinical advantages.16 Therefore, echogenic catheters may have an important role in clinical practice by facilitating placement confirmation, especially when performing the more efficient short-axis, in-plane technique.

Despite differences in echogenicity and the percentage of catheter visualized, there were no differences in scanning times in this study. We speculate that the expert who performed the ultrasound scanning used a standardized, systematic approach. Perhaps catheter tip identification, especially differentiation from the catheter shaft, remains difficult even with improved echogenic technology unless the technology is differentially applied to the shaft and tip. The use of a standardized in vitro porcine-bovine study model with fixed parameters, as described in the study pro-

### Table 1. Catheter Visibility Scores and Definitions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Visibility Score, 0–10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall visibility</td>
<td>Describes the overall quality of the catheter image alone.</td>
<td>High value means good visibility; low value describes near invisibility.</td>
</tr>
<tr>
<td>Artifact</td>
<td>Describes the amount and degree of artifact formation; possible artifacts include scattering, reverberation, and multiple echoes, but “shadowing” is excluded.</td>
<td>Low value is rated good; high value is associated with greater artifacts, marked by reduced image quality of the vicinity surrounding the catheter.</td>
</tr>
<tr>
<td>Shadowing</td>
<td>Describes the amount and degree of shadows.</td>
<td>Low value is rated as good visibility beyond the catheter; high value describes a near absence of the image beyond the catheter.</td>
</tr>
<tr>
<td>Contrast</td>
<td>Describes the appearance of the catheter compared to surrounding tissue inside the model.</td>
<td>High value means good contrast; low value describes a catheter that is very difficult to identify and differentiate from surrounding media.</td>
</tr>
</tbody>
</table>

Adapted from Maecken et al.5

### Table 2. Secondary Outcome Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B. Braun Contiplex</th>
<th>Arrow StimuCath</th>
<th>Epimed Ultra-Kath</th>
<th>B. Braun PeriFix FX</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall echogenicity ranking, 1–4</td>
<td>2 (1–4)</td>
<td>3 (2–4)</td>
<td>2 (1–4)</td>
<td>3 (1–4)</td>
<td>.002</td>
</tr>
<tr>
<td>Echogenicity visibility, 0–10</td>
<td>5.4 ± 2.4</td>
<td>4.9 ± 1.6</td>
<td>6.6 ± 1.5</td>
<td>5.0 ± 2.3</td>
<td>.075</td>
</tr>
<tr>
<td>Artifact score, 0–10</td>
<td>6.0 (2–6)</td>
<td>4.0 (2–7)</td>
<td>6.5 (2–75)</td>
<td>5.5 (2–8)</td>
<td>.295</td>
</tr>
<tr>
<td>Shadowing score, 0–10</td>
<td>6.0 (1–9)</td>
<td>5.5 (2–7)</td>
<td>6.0 (1–8)</td>
<td>6.0 (1–7)</td>
<td>.658</td>
</tr>
<tr>
<td>Contrast score, 0–10</td>
<td>4.5 (2–10)</td>
<td>5.5 (2–10)</td>
<td>7.0 (3–8)</td>
<td>5.5 (1–9)</td>
<td>.307</td>
</tr>
<tr>
<td>Scan time, s</td>
<td>24 (11–54)</td>
<td>36 (8–76)</td>
<td>20 (9–59)</td>
<td>20 (14–62)</td>
<td>.306</td>
</tr>
<tr>
<td>Estimated catheter length, %</td>
<td>60 (35–90)</td>
<td>60 (10–90)</td>
<td>70 (20–90)</td>
<td>70 (40–80)</td>
<td>.925</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD and median (range) as applicable.

*P* = .008 versus Arrow StimuCath.

*P* = .001 versus Arrow StimuCath; *P* = .19 versus B. Braun PeriFix FX.

*P* = .200 versus Arrow StimuCath; *P* = .270 versus B. Braun PeriFix FX.
Protocol, including a uniform 4-cm insertion depth, may have contributed to the similar scanning times as well. Direct visualization of the catheter during placement may save additional procedural time by avoiding postplacement maneuvers to infer the catheter location. In a previous study, the air test was shown to provide high sensitivity and specificity for correct catheter tip placement and was preferred over chance. Potential effects of the injection of air on the nerve itself or subsequent distribution of injectate solution on nerve block quality are unknown. Furthermore, the injection of air introduces an artifact near the target that can, in theory, affect subsequent catheter replacement if it becomes necessary, and a misplaced intravascular catheter may inadvertently lead to an air embolus, which fortunately is unlikely to lead to detrimental effects when the injected volume is small.

Other methods described to infer the perineural catheter location include radiography with contrast, injection of agitated fluid under ultrasound guidance, and administration of fluid with color Doppler imaging to detect turbulence. All of these alternative techniques are performed after catheter placement and require additional steps and supplies, which add to the total procedural time without established benefits compared to the air test or direct catheter visualization.

Figure 3. Representative ultrasound images of the 4 regional anesthesia catheters included in the study. A. B. Braun Contiplex 20-gauge nonstimulating catheter. B. Arrow StimuCath 19-gauge stimulating catheter. C. Epimed Ultra-Kath 21-gauge nonstimulating flexible wire reinforced peripheral nerve block catheter. D. B. Braun PeriFix FX 19-gauge nonstimulating catheter. Arrowheads indicate distal ends of the catheters.
The accuracy of catheter tip placement is critical to maximizing the analgesic benefits of perineural infusion.\textsuperscript{19,26} Furthermore, inadvertent vascular puncture and other complications may still occur during ultrasound-guided regional anesthesia,\textsuperscript{27,28} building a strong case for the application of echogenic technology to perineural catheters. Other technological advances, such as 3-dimensional ultrasound imaging and catheter vibration,\textsuperscript{29,30} may represent future options for improving catheter visualization, but access to new technology will not be available to every clinician. In addition, echogenic technology for regional anesthesia catheters may have potential applications for indwelling catheters used for other indications.\textsuperscript{31,32}

One limitation of this study was the use of an in vitro meat phantom model. This model has been previously validated,\textsuperscript{15,33} but there may be differences between nonliving porcine-bovine tissue and actual humans. We did not involve live patients or volunteers, since one of the catheters under study is still in development and awaiting approval from the US Food and Drug Administration. Another limitation related to the in vitro model was the inability to assess the influence of catheter visibility and position on clinical anesthetic or analgesic efficacy. Finally, the results of this study apply only to the catheter insertion technique and specific catheter and ultrasound equipment included and cannot be applied to other placement techniques or catheter and ultrasound equipment types and brands.\textsuperscript{27,34,35} Measures of echogenicity used in this study are subjective and difficult to assess. We adapted outcome measures used by Maecken et al\textsuperscript{5} for needle visibility; some of these measures may not be relevant for perineural catheters. The subjective nature of echogenicity and image quality is shown by the artifact, shadowing, and contrast score variability among the catheters studied. More objective measurements of pixel intensity have been described but may be limited to catheter assessment at shallow depths and angles,\textsuperscript{11} which may not be broadly applicable to clinical practice.

In conclusion, results from this in vitro study demonstrate that catheters used for regional anesthesia display a wide range of echogenicity. This study serves as a proof of concept that regional anesthesia catheters can be made more echogenic. Incorporating an internal wire braid may improve visibility with ultrasound compared to commercially available, larger-gauge alternatives. However, further studies are required to show whether this echogenic advantage observed in a nonliving animal model translates to greater analgesic efficacy with continuous peripheral nerve blocks in clinical practice.

References


