The Effects of Needle Type, Gauge, and Tip Bend on Spinal Needle Deflection

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Although the use of fine-gauge spinal needles reduces the incidence of postdural puncture headache, they are associated with increased risk of placement failure as a result of deflection and bending. This *in vitro* study quantifies spinal needle deflection from the axis of insertion with respect to needle type, gauge, and tip bend. In addition to straight-tip needles, those with standardized 5° and 10° tip bends were studied. The purpose was to examine the effect of tip bend, which has been described with small gauge spinal needles after bony contact, on needle path deflection. Needles studied included Quincke (Q), Sprotte (S), and Whitacre (W) in sizes ranging from 18-gauge to 29-gauge. Needles were inserted perpendicularly into porcine paraspinous muscle followed by radiologic investigation. Measurements of needle deflection from the axis of insertion at depths of 20, 40, and 60 mm were performed in a blinded fashion. Straight-tip Q needle deflection, but not W or S, was correlated with gauge and depth of insertion. Although there were differences within needle type groups, needle deflection was generally correlated with the degree of tip bend. We conclude that spinal needle deflection is dependent on the type of needle (W < S < Q), and that the magnitude of deflection is related to gauge (large < small) and tip bend (straight < 5° < 10°).

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The increased use of spinal anesthesia for ambulatory and obstetric surgery has been attributed to a decreased incidence of postdural puncture headache. This lower rate of postdural puncture headache is associated with the use of smaller gauge needles and those with pencil-point tips (1–5). Although improvements in manufacturing techniques have enabled the production of smaller gauge needles (6,7), their use is associated with practical limitations, such as higher rates of placement failure. This may be a result of deflection of the needle shaft from its axis of insertion and deformation of the needle tip after bony contact. Even if dural puncture has been achieved, the slow rate of cerebrospinal fluid flow, and the potential for needle lumen occlusion, may mask or delay confirmation of a successful placement (8–11). Limited studies of needle path deviation of both spinal needles and small gauge beveled dental needles have been performed (12–16). This study was designed to quantify and compare the path deflection from the axis of insertion of commonly used spinal needle types and gauges. Additionally, in view of clinical reports of significant spinal needle tip bending with bony contact (17,18), we have attempted to recreate this clinical scenario by placing needle tip bends in a standardized fashion and quantifying this effect on needle path deflection.

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Methods

Spinal needles selected for evaluation were 18-, 20-, 22-, 25-, 27-, and 29-gauge Quincke (Q) (Becton Dickinson, Franklin Lakes, NJ), 22-, 25-, and 27-gauge Whitacre (W) (Becton Dickinson), and 22- and 25-gauge Sprotte (S) (Havel's Inc., Cincinnati, OH) (Figure 1). All needles evaluated were 8.9 cm long. Needles were inserted through one of five 2.54-cm 16-gauge introducers into a radiolucent plexiglass frame containing porcine paraspinous muscle (erector spinae group). Introducers were secured within precision-drilled holes into the porcine muscle, to provide accurate alignment of the needles. All spinal needles, with stylets in place, were manually inserted perpendicular to the muscle fibers with uniform force by one of the investigators. Introduction sites were randomly selected to decrease potential bias from lack of muscle sample homogeneity. Q needles were inserted with their bevels facing laterally, perpendicular

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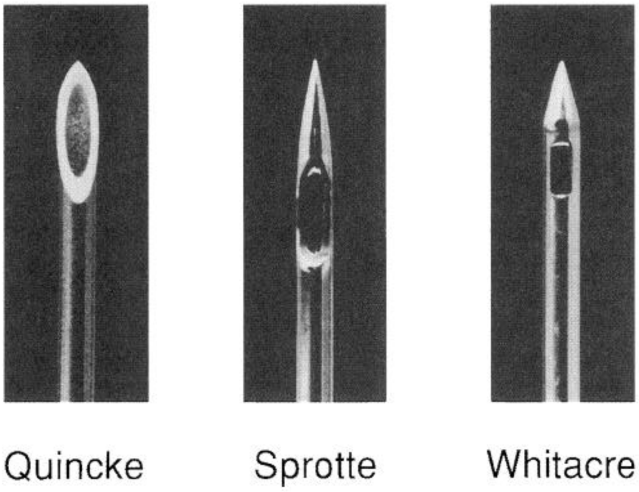

Figure 1. Magnified view of 22-gauge Quincke, Sprotte, and Whitacre spinal needle tips.

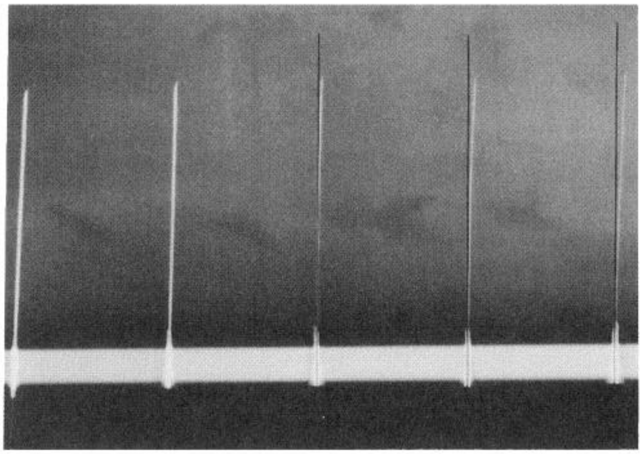

Figure 2. Radiograph of straight-tip Quincke spinal needles within porcine paraspinous muscle. From left to right: 18-, 20-, 22- 25-, and 27-gauge. Note deflection from the axis of insertion (vertical black line).

to the muscle fiber. W and S needles were inserted with their distal side ports facing laterally.

After insertion of spinal needles through each of the five introducers, plain radiographs were taken on a General Electric (Milwaukee, WI) MVP80 radiograph machine using standard technique (1.25 mA, 60 kV) on 8 × 10-inch film (Figure 2). Needle deflection (mm) from the axis of insertion was determined at depths of 20, 40, and 60 mm using a superimposed calibrated grid which compensated for image magnification occurring during the radiograph process. The investigator measuring the needle deflection from the radiographs was blinded to individual needle characteristics.

In addition to straight-tip needles, spinal needle tips were bent at 5° and 10° angles using microcalipers and needle pliers adapted for this purpose. Q needles had bends induced 5 mm from their tips in a direction away from the bevel. One set of W needles had bends induced 5 mm from their tips, while a second set of W needles had similar bends induced at their side ports (1.5 mm from the tip). S needles had bends induced at their side ports (2.5 mm from the tip). Bends were induced toward the distal side ports of the W and S needles. Deflection of bent-tip needles, with their bevel or distal side port facing laterally, was evaluated using the method discussed above.

Five needles of each type, gauge, and tip bend were studied. Data are expressed as mean ± SEM. Spinal needle deflection differences based on needle type, gauge, and degree of tip bend were analyzed using one-way analysis of variance. When overall significance was present, *post hoc* Tukey's comparisons of means testing was performed. Least squares linear regression analysis was performed to determine the relationship between total deflection of each needle type and gauge. Statistical significance was considered when $P < 0.05$.

Results

Deflection at depths of 20, 40, and 60 mm for all spinal needles studied is displayed in Table 1.

Straight Needles

Deflection of straight Q needles at a depth of 60 mm ranged from 0.0 mm (18-gauge) to 3.4 ± 0.6 mm (29-gauge). Q straight tip needle deflection was uniformly away from the direction of the bevel face and was significantly correlated with needle gauge ($r = 0.918$, $P < 0.005$) (Figure 3). There was no significant correlation between deflection and gauge with straight tip W and S needles.

Twenty-two-gauge W needles had significantly less deflection than 22-gauge S and Q needles ($P = 0.05$). Both 25-gauge W and S needles had significantly less deflection than 25-gauge Q needles ($P < 0.01$). Although mean deflection of 27-gauge W needles was nearly half that of 27-gauge Q needles at all depths, statistical significance was not achieved.

Needle Tip Bends

Needle tip bends of 5° and 10° resulted in greater deflection from the midline than with straight needles. Deflection at 60 mm for 25-, 27-, and 29-gauge Q needles bent at 5° and 10° was 3 to 9 times greater than deflection with equivalent sized straight-tip Q needles. Maximum deflection from the axis of insertion was recorded with the 29-gauge Q needle bent at 10° (31.7 ± 4.8 mm at 60 mm depth).

When Q needles bent 5 mm from the needle tip were compared with W and S needles bent at their

Table 1 Effects of Needle Type, Gauge, and Tip Bend on Spinal Needle Deflection at Depths of 20, 40, and 60 mm

Type	Gauge	Tip bend[a]	Needle tip deflection at depth of: 20 mm	40 mm	60 mm
Quincke	18	None	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Quincke	20	None	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1
Quincke	22	None	0.0 ± 0.0	0.3 ± 0.1	0.6 ± 0.2
	22	5°	0.3 ± 0.2	1.0 ± 0.3	1.8 ± 0.3
	22	10°	0.7 ± 0.3	1.7 ± 0.4	2.5 ± 0.8
Sprotte	22	None	0.0 ± 0.0	0.1 ± 0.1	0.3 ± 0.2
	22	5°[b]	0.0 ± 0.0	0.5 ± 0.3	0.8 ± 0.4
	22	10°[b]	0.2 ± 0.2	0.7 ± 0.2	1.5 ± 0.3
Whitacre	22	None	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	22	5°	0.0 ± 0.0	0.5 ± 0.3	1.2 ± 0.6
	22	10°	0.3 ± 0.3	1.0 ± 0.6	2.2 ± 1.0
	22	5°[b]	0.0 ± 0.0	0.2 ± 0.1	0.5 ± 0.3
	22	10°[b]	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.2
Quincke	25	None	0.1 ± 0.1	0.6 ± 0.2	1.2 ± 0.3
	25	5°	0.8 ± 0.2	2.5 ± 0.3	4.7 ± 0.6
	25	10°	1.8 ± 0.4	3.8 ± 1.3	7.0 ± 2.7
Sprotte	25	None	0.0 ± 0.0	0.1 ± 0.1	0.3 ± 0.2
	25	5°[b]	0.3 ± 0.2	1.2 ± 0.3	2.3 ± 0.4
	25	10°[b]	0.8 ± 0.6	2.3 ± 0.9	4.8 ± 1.6
Whitacre	25	None	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	25	5°	0.7 ± 0.3	2.0 ± 0.5	3.7 ± 0.6
	25	10°	1.5 ± 0.3	3.2 ± 0.9	6.0 ± 1.6
	25	5°[b]	0.2 ± 0.2	0.3 ± 0.3	0.7 ± 0.4
	25	10°[b]	0.5 ± 0.3	1.5 ± 0.9	2.7 ± 1.3
Quincke	27	None	0.6 ± 0.1	1.6 ± 0.2	2.8 ± 0.4
	27	5°	1.7 ± 0.6	4.3 ± 1.0	8.2 ± 1.7
	27	10°	2.3 ± 0.3	5.3 ± 1.2	10.0 ± 2.5
Whitacre	27	None	0.3 ± 0.2	0.9 ± 0.4	1.4 ± 0.6
	27	5°	1.7 ± 0.2	3.5 ± 0.3	6.8 ± 0.6
	27	10°	2.8 ± 0.4	7.2 ± 1.2	13.2 ± 1.7
	27	5°[b]	0.0 ± 0.0	0.2 ± 0.2	0.8 ± 0.2
	27	10°[b]	0.2 ± 0.2	0.5 ± 0.3	1.2 ± 0.4
Quincke	29	None	0.5 ± 0.2	1.9 ± 0.4	3.4 ± 0.6
	29	5°	3.8 ± 0.7	10.0 ± 1.3	20.0 ± 2.3
	29	10°	4.8 ± 0.9	14.3 ± 2.2	31.7 ± 4.8

Values are mean ± SEM; $n = 5$.
[a] Bends are at 5 mm from the spinal needle tip unless otherwise noted.
[b] Whitacre and Sprotte tip bends at the distal port.

distal side ports, there was significantly less deflection of 22-gauge W compared with 22-gauge Q and S needles (at 10°, $P < 0.05$). There was also significantly less deflection of 25-gauge W and S needles compared with 25-gauge Q (at 5°, $P < 0.005$), and significantly less deflection of 27-gauge W compared with 27-gauge Q (at 5° and 10°, $P < 0.05$) (Figure 4).

When Q and W needles bent 5 mm from the tip were compared, there were no significant differences in deflection at either 5° or 10° for any of the gauges studied.

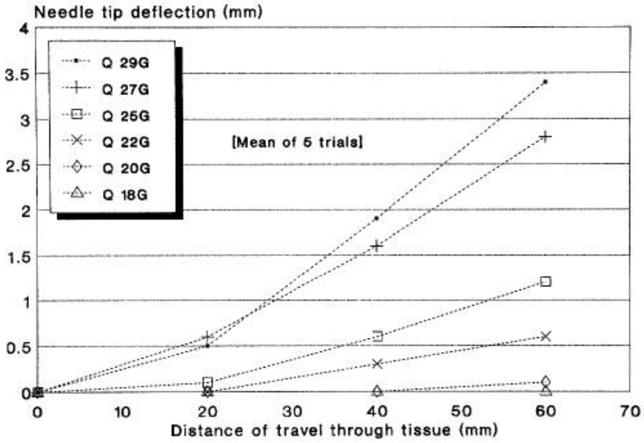

Figure 3. Straight-tip Quincke (Q) spinal needle deflection relative to the depth of insertion. A significant positive linear correlation between Q straight-tip needle deflection and needle gauge (G) was observed ($r = 0.918$, $P < 0.005$).

Discussion

Practical constraints and anatomic complexity precluded our use of an *in vivo* investigation or that of an *in vitro* model of midline anatomy. Nevertheless, we consider our porcine paraspinous muscle model to be a valid representation of the paramedian route to the subarachnoid space. The use of introducer needles in this study eliminated the need to incorporate skin and subcutaneous structures into our model.

Our findings of Q needles deflecting away from the tips' bevel surface confirm the work of Drummond and Scott (12). We determined spinal needle deflection of depths of 20, 40, and 60 mm, thereby reproducing the range of likely distances traveled to the subarachnoid space in clinical practice (19,20). This has more clinical significance in obese patients in whom the depth of spinal needle insertion, and thus deflection, are both likely to be greater. Various solutions to address Q needle deflection from the axis of insertion have been described. These include insertion of the needle with the bevel introduced either cephalad or caudad with subsequent 180° rotation to maintain the needle in the midline (21,22) and offsetting the bevel-induced deflection by linear displacement of the skin at the site of needle insertion (23). The most appropriate solution in clinical practice is to insert fine-gauge Q needles through an introducer (6,24). This protects the spinal needle tip from unnecessary damage sustained from the penetration of superficial tissue and maintains the needle along the axis of insertion. The use of a Tuohy needle as an introducer, such as that used with a combined spinal-epidural technique, is advantageous in that the epidural needle guides and places the fine-gauge spinal needle in close proximity to the subarachnoid space (25).

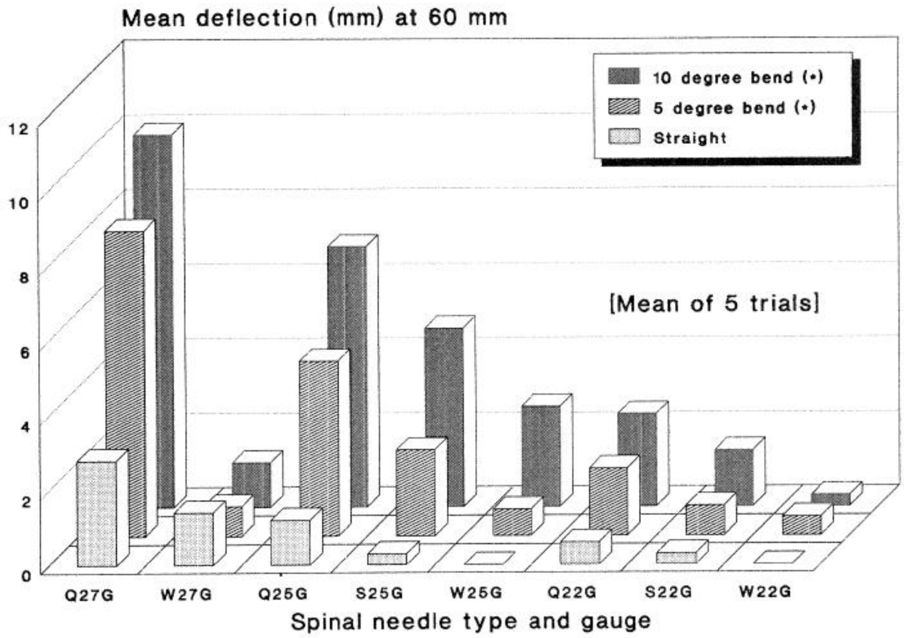

Figure 4. Effects of tip bend on spinal needle deflection at 60 mm depth. *Quincke (Q) bends at 5 mm from the needle tip, Sprotte (S) and Whitacre (W) bend at their distal ports. Note the greater deflection of Q needles compared with S and W needles of equal gauge (G) and bend profile.

Straight pencil-point needle (W and S) deflection from the axis of insertion was significantly less than Q needle deflection in general. Pencil-point needle deflection was primarily in the direction of the distal side port, suggesting the possibility of increased "drag" induced by the irregularity of the side port. Alternatively, the force required to insert these needles may have been sufficient to induce a slight flexion of the needle tip at an area of weakness (i.e., the side port) resulting in slight distortion of the pencil-point tip and hence deflection. Lipov et al. (18) demonstrated that the axial force needed to deform the S needle tip was less than that needed for the W and Q needles of similar size. The larger distal side port of the S needle, as well as its greater distance from the tip, may account for the slightly greater deflection observed with S needles compared to W needles based on the mechanisms postulated above.

Bends of 5° and 10° at the side ports of W and S needles recreated needle tip damage reported with the use of pencil-point needles (17,18). Differences in deflection between W and S needles with side port bends may be explained by the closer proximity of the W side port to the needle tip compared to the S side port (Figure 1). With the methods used in this study, distal bends induced in Q needles were reliably reproducible only at 5 mm from the tip. We therefore bent a second set of W needles at 5 mm from their tips to serve as a direct comparison. This study clearly demonstrates that straight pencil-point needle deflection is less than that of Q needles; however, deflection is similar with W and Q needles bent at 5 mm from their tips. This suggests that the reduced deflection which straight W needles possess over straight Q needles may be lost with even minor tip bending. This finding would appear to endorse recommendations of clinicians and needle manufacturers to discard pencil-point needles if their insertion is complicated by a needle tip bend resulting from significant contact with bone. Although there is some variability, this study demonstrates that spinal needle deflection from the axis of insertion is dependent of the type of needle (W < S < Q), with the magnitude of deflection related to gauge (large < small), tip bend (straight < 5° < 10°), and depth of insertion.

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