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Original Research Article

Differential Rates of Inadvertent Intravascular Injection during Lumbar Transforaminal Epidural Injections Using Blunt-Tip, Pencil-Point, and Catheter-Extension Needles

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Abstract

Objective. To quantify the incidence of inadvertent vascular penetration during lumbosacral transforaminal epidural injections using blunt-tip, pencil-point, and catheter-extension needles.

Study Design/Setting. This is a prospective, observational, consecutive cohort study.

Subjects. Two hundred consecutive patients undergoing lumbosacral transforaminal epidural injections at an academic outpatient spine center.

Methods. Four hundred seventy-five fluoroscopically guided lumbosacral transforaminal epidural injections were performed on consecutively consenting patients by one interventional spine physician, using three different needle types. The presence or absence of vascular uptake was determined during contrast injection under live fluoroscopy.

Results. Vascular uptake of contrast was observed in 58 of the total 475 injections, for an overall incidence of 12.2%. By needle type, the incidence of inadvertent vascular uptake was 16.6% (26/157) in the pencil-point group, 15.6% (24/154) in the blunt-tip group, and 4.9% (8/164) in the catheter-extension group. The difference in rates is statistically significant between the catheter-extension needle group and both the pencil-point group ($P = 0.0009$) and blunt-tip group ($P = 0.0024$). A secondary analysis was performed to quantify the incidence of functional pitfalls between needle groups, with a significantly lower incidence in the pencil-point group compared to both the catheter-extension ($P = 0.0148$) and blunt-tip needle ($P = 0.0288$) groups.

Conclusions. Blunt-tip and pencil-point needles have comparable risk of inadvertent vascular injection during lumbosacral transforaminal injections. Catheter-extension needles demonstrated a reduce incidence of vascular uptake, but also result in a

significantly higher rate of functional pitfalls that limits their usefulness in routine practice.

Key Words. **Transforaminal; Lumbar; Epidural; Fluoroscopy**

Introduction

Despite overall low rates of minor complications, [1] lumbar transforaminal epidural injections are not exempt from serious morbidity. Case reports of spinal cord infarction secondary to inadvertent arterial injection of certain corticosteroids are now widely known in the field [2–4]. Though the artery of Adamkiewicz most commonly arises between T9 and L2 in 85% of individuals, it has been observed to originate as caudally as the sacrum [3,5]. Inadvertent intravascular contrast injection occurs in 8.1–21.3% of fluoroscopically guided lumbar transforaminal epidural injections, with some variation between different levels of the lumbosacral spine [6–8]. Thus, careful observation of the dynamic spread of contrast under live fluoroscopy is essential to identify inadvertent vascular trespass [9].

A few studies have focused attention on the impact of various needle types on potential complications. In animal studies blunt-tip needles appear less likely to enter blood vessels and produced less bleeding relative to the more traditional sharp-beveled needles [10,11]. The Trucath Spinal Injection System (Smith & Nephew, Inc., London, UK) consists of a blunt-tip, side-port catheter that is extended past the tip of a traditional sharp-beveled needle. One study of this needle found a significantly lower incidence of vascular uptake with this needle, compared to standard sharp-bevel needles, during cervical transforaminal injections [12]. Pencil-point needles have a noncutting pointed tip designed to separate tissue planes, and have been shown to cause fewer postlumbar puncture headaches in comparison to traditional sharp-beveled needles when used in lumbar puncture and myelography [13,14]. At different times, each of these different needles has been suggested for use in transforaminal epidural injections for the purpose of improved safety [11,12].

To date, the relative incidence of vascular injection among these needles remains unknown. This study was performed to quantify the incidence of inadvertent vascular injection during the performance of lumbosacral transforaminal epidural injections with blunt-tip, catheter-extension, and pencil-point needles.

Methods

This prospective, observational, consecutive cohort comparison study was institutional review board approved and Health Insurance Portability and Accountability Act compliant. It is a protocol continuation of data collected previously and published for comparison of short-bevel "Chiba" needles and conventional long-bevel "Quincke" needles [15]. All injections were performed in the manner previously described, using the same brand and size of c-arm fluoroscope, and data collected by the same interventional physiatrist at a university-based spine clinic.

Figure 1 The first consecutive cohort was treated using 25-guage pencil point needles (A), followed by the cohort using 22-guage blunt-tip needles (B), and finishing with the cohort using 20-guage catheter-extension needles (C). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Consecutive consenting patients were enrolled into the three different sequential cohorts that are compared in this study. Any patient scheduled for a lumbosacral transforaminal epidural injection, at the request of the treating physiatrist or spine surgeon, was considered for inclusion in this study and approached for enrollment in the pre-operative area. Exclusion criteria included pregnancy, coagulopathy, systemic infection, contrast allergy, mental disability, and inability to provide informed consent. A total of 475 lumbosacral transforaminal epidural injections were performed on 200 consecutive consenting patients.

The first consecutive cohort was treated using 25-gauge pencil-point (Whitacre) needles, followed by the cohort using 22-gauge blunt-tip needles, and finishing with the cohort using 20-gauge catheter-extension (Trucath) needles (Figure 1). For all subjects, the needle was placed under intermittent fluoroscopic guidance to locate the needle tip at or immediately lateral to the 6-O'clock position of the pedicle, as was previously performed and reported for the study of Chiba and Quinke needles. The sole exception to this standardized technique was the placement of the catheter-extension needles. As the catheter advances anteromedial from the

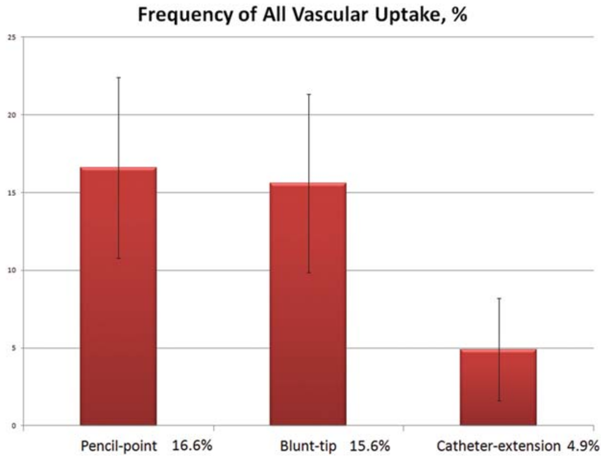

Figure 2 Within the different cohorts, the incidence of vascular injections was 26/157 in the pencil-point group (16.6%±5.81), 24/154 in the blunt-tip group (15.6%±5.73), and 8/164 in the catheter-extension group (4.9%±3.3). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

tip of this needle, the needle tip was intentionally placed a few millimeters lateral and posterior to the intended location of the needle tip for the other needle types, allowing room for deployment of the catheter. For all injections, once the needle tip (or catheter) placement was deemed sufficient, live anteroposterior fluoroscopy was used to observe the injection and flow of at least 0.5 cc of radiopaque contrast. A single author (MS) was responsible for confirming final needle placement and characterizing the dynamic contrast pattern observed under live fluoroscopy. Immediately after the contrast injection, the observed pattern of this initial injection was recorded as one of the following categories: epidural only, vascular only, or mixed epidural and vascular. For data analysis purposes, the latter two categories were combined into an "all vascular" group. If an extraspinal soft-tissue contrast pattern was initially observed, it was disregarded and the needle tip repositioned until one of the above contrast patterns was produced and recorded. Digital subtraction was not used in this study.

If vascular contrast uptake was observed, the needle was repositioned by initially withdrawing the needle 2–3 mm. Contrast was again injected under live fluoroscopy. This repositioning and contrast injection was repeated two to three times if necessary. If these attempts failed to eliminate vascular contrast patterns, the needle tip was withdrawn further and repositioned more inferiorly within the neuroforamen. Once an "epidural only" pattern was observed, the treatment solution was injected, however, only the initial contrast pattern was recorded for this study.

Additional data collected for each injection included patient age, sex, diagnosis, side, and level of injection, number of attempts required to position the needle before successful injection of the treatment solution, fluoroscopy time, and if the subject had a previously recorded injection in the study. Separate records were created for each injection if more than one injection was performed on a single subject. Statistical analysis was performed using Fisher exact test.

Results

A total of 475 injections were performed on 200 consecutive consenting participants. Some patients had injections at more than one level, and some returned for repeat injections accounting for the total 475 injections. The first 157 injections were completed using pencil-point needles, the next 154 using blunt-tip needles, and the final 164 using catheter-extension needles. Participants had a mean age of 58.3 years (range 18–92 years) with a 51/49% male/female ratio. Diagnoses leading to treatment with epidural injection included radiculopathy ($n = 316$), lumbar stenosis ($n = 194$), herniated nucleus pulposus ($n = 106$), degenerative disc disease ($n = 30$), and postsurgical spine ($n = 71$) with most subjects having more than one of these diagnoses and all subjects having at least one of the first two listed diagnoses. No serious complications were observed in any of the patients treated in this study.

Vascular contrast uptake was observed in 58 of the total 475 injections, for an overall incidence of 12.2%. For the primary outcome analysis, all injections were classified into their respective cohorts based on needle type. Within the different cohorts, as show in Figure 2, the incidence of vascular injections was 26/157 in the pencil-point group (16.6% ±5.81), 24/154 in the blunt-tip group (15.6% ±5.73), and 8/164 in the catheter-extension group (4.9% ±3.3). The differences between observed vascular injection rates is statistically significant between the catheter-extension group and the pencil-point group ($P = 0.0009$), and between the catheter-extension group and the blunt-tip group ($P = 0.0024$). Table 1 contains further details.

For secondary outcomes, we examined pitfalls that occurred with the use of each needle type. No functional pitfalls where observed during the 157 injections using pencil-point needles. With the blunt-tip needles, bent needles occurred in two cases requiring us to change to another needle. Another three demonstrated initial vascular uptake and subsequent inability to obtain an extravascular epidural injection. Surprisingly, this occurred despite multiple attempts to reposition the needle tip, and even after withdrawing the needle all of the way back out of the intertransverse membrane and moving to a more inferior position before penetrating the membrane again to enter the foramen. Thus, there was a total of five injection failures using the blunt-tip needles (5/154 = 3.2% pitfall incidence). In the injections using catheter-extension needles, 1 catheter was bent and did not allow medication delivery, and another six cases failed due to medication regurgitation via the needle lumen (7/164 = 4.3%

Table 1 Vascular injection by needle tip type

Group by observed contrast pattern	Pencil-point (n=157) %, 95%CI (n)	Blunt- tip (n=154) %, 95%CI (n)	Catheter-extension (n=164) %, 95%CI (n)
Epidural only	83.44, ±5.81 (131)	84.41, ±5.73 (130)	95.12, ±3.3 (156)
Vascular only	5.1, ±3.44 (8)	4.55, ±3.29 (7)	2.44, ±2.36 (4)
Mixed epidural and vascular	11.46, ±4.98 (18)	11.04, ±4.95 (17)	2.44, ±2.36 (4)
All vascular	16.56, ±5.81 (26)	15.6, ±5.73 (24)	4.9, ±3.3 (8)*

* Statistically significant lower incidence of all vascular injections with use of catheter-extension in comparison with use of pencil-point ($P = 0.0009$) and blunt-tip groups ($P = 0.0024$).

pitfall incidence). In these latter cases, the medication was injected into the patients thru the catheter, then tracked along the outside of the catheter and back up the space between the catheter and the needle wall to exit via the needle lumen and out the needle hub. In each case, this occurred despite full catheter deployment. Comparisons of the pitfall incidence demonstrated statistically significant difference between pencil-point needles and both the catheter-extension ($P = 0.0148$) and the blunt-tip needles ($P = 0.0288$), with no difference between catheter-extension and the blunt-tip needles ($P = 0.7714$) (Table 2).

Discussion

Best practice necessitates that all physicians who perform percutaneous procedures be aware of both the risks of inadvertent vascular puncture and the methods that are verified to reduce these risks. It is a common fallacy for innovative treatments and devices to be met with a less critical eye because of unsubstantiated early anecdotal claims and premature enthusiasm for potential theoretical advantages [16]. It is imperative to avoid such mistakes, and evaluate novel medical treatments with appropriate skepticism, especially regarding assertions of safety that are yet unproven.

The 4.9% incidence of inadvertent vascular injections observed with catheter-extension needles is significantly lower than that seen with use of blunt-tip (15.6%) and pencil-point (16.6%) needles. Importantly, these rates are directly comparable to rates observed in our previous study of Quincke (12.8% incidence) and Chiba (15.6% incidence) needles [15], as the current findings are a continuation of the same IRB approved protocol and data collection procedures as used for the earlier published report. The results from these two studies are shown together in Table 3. Summating the data from these studies, inadvertent vascular injections during lumbosacral transforaminal epidural injections are similar between pencil-point, blunt-tip, Chiba, and Quincke needles with no observed vascular safety advantage for one over the other. Catheter-extension needles do produce a lower rate of inadvertent vascular injection, however with a statistically higher failure rate due to pitfalls. The incidence reported here, and in the former study [15], reflect rates observed under standard live fluoroscopy. Some have reported increased detection using digital subtraction [17–19], which was not used during any injections in this study.

Table 2 Functional pitfalls by needle type

Needle Type	Functional pitfalls, % (n)
Pencil-point (n=157)	0 (0)*
Blunt-tip (n=154)	3.2 (5)
Catheter-extension (n=164)	4.3 (7)

* Pencil-point group had statistically significant lower incidence of pitfalls in comparison to blunt-tip ($P = 0.0288$) and catheter-extension ($P = 0.0148$) groups. No difference found in pitfall rates between catheter-extension and blunt-tip groups ($P = 0.7714$).

The possible mechanisms by which catheter-extension needles produce lower rates of vascular uptake have not been studied or proven. Hypothetically, several factors may contribute. The flexible nature of the extendable catheter may deflect off vascular structures rather than penetrate them. Or, it is possible that the larger size (20 gauge) of the introducer needle may be less likely to cannulate small vessels, though prior studies have failed to reveal a difference in vascular uptake based on needle gauge [15]. Specifically, no difference occurred between injections using a 25-gauge Chiba needle (n = 64), a 25-gauge Quincke needle (n-16), or a 26-gauge Quincke needle (n-78). Lastly, the placement of the catheter-extension needle lateral and posterior to

Table 3 All vascular injections

Needle type	Vascular uptake %	95% CI
Quinke	12.8	±6.25
Chiba	15.6	±8.89
Pencil-point	16.6	±5.81
Blunt-tip	15.6	±5.73
Catheter-extension	4.9	±3.3

the 6-O'clock position of the pedicle for deployment of the catheter is a location that less frequently contains radicular arteries [20,21], though no studies currently describe the relative frequency of venous structures in these locations.

Differing mechanisms of needle-induced tissue trauma may be responsible for the vascular uptake observed in needles specifically designed to reduce it. A common theory regarding the decreased rates of postdural puncture headache from blunt and pencil-point needles attributes this observation to less traumatic injury of the dura relative to the cutting action of sharp-beveled needles [22]. While it is true that blunt-tip and pencil-point needles separate tissues when travelling along tissue planes, penetration through tissue planes actually results in larger and more irregular tissue defects relative to the cutting mechanism of the sharp-beveled needles. Some have suggested that this irregular defect promotes an inflammatory responses that speeds dural healing and reduces cerebrospinal fluid loss [23,24]. We suspect that that this same mechanism results in different vascular trauma between sharp-beveled needles and the blunt-tip or pencil-point needles. One of the curious findings in this study was the occasional persistence of vascular uptake with blunt-tip needles, despite repositioning the needle into more posterior and inferior locations within the neuroforamen. Interestingly, in these cases the vascular pattern that appeared was always the same pattern regardless of changes in the needle tip position, thus contrast continued to flow into the same vascular structure. We hypothesize that the thin-walled veins within the foramen are particularly vulnerable to the blunt-force trauma of these needles; and once a large traumatic defect is produced in a larger foraminal vein, it may become the path of least resistance for the pressurized injection of contrast anywhere in its vicinity.

Familiarity with needle types and their perceived ease of use impact the frequency with which practitioners choose them. All three needle types reviewed in this study have inherent functional weaknesses that, without clear evidence of benefit, will limit widespread acceptance in percutaneous procedures around the spine. The relative benefits and drawbacks of the needles used in this study can be summarized as follows. Blunt-tip and pencil-point needles lack the steerability of the traditional sharp-beveled needles, and patients may experience more pain from the greater force required to pass the blunted needles across the several tissue planes encountered between the skin and the spine [25]. Introducer needles can eliminate some of these issues, but require passage of much larger gauge needles. Catheter-extension needles have a sharp-beveled tip, however those who prefer bent needles have to be cautious about manipulating the tip of a needle with an indwelling catheter. The catheter itself is not always easy to deploy, especially in the setting of a degenerative stenotic foramen. Also, reports of shearing various flexible catheters inside of patients during epidural procedures is another potential concern [26–28].

Still, the catheter-extension needles alone showed a statistically significant reduction in the rate of inadvertent vascular injection. This corroborates data observed by Kloth et al, in a study of cervical transforaminal injections. They described a 10.6% vascular uptake rate with catheter-extension needles versus 26.8% using conventional sharp-beveled needles [12]. Like our study, they also observed a higher frequency of functional pitfalls with the catheter-extension needles. While specifically designed to reduce tissue injury by deflecting off vascular and neural structures, both studies observed catheter kinking even with ideal needle tip localization, preventing drug delivery to the epidural space. Lastly, we observed several cases of regurgitation of the steroid solution from the catheter, back up the lumen of needle and out the needle hub. This happened even with ideal placement of the needle and full deployment of the catheter. Thus, the dose of treatment medication delivered by this needle could not always be accurately determined.

The results of this study dispel the common misconception that blunt-tip and pencil-point needles reduce the risk of inadvertent vascular cannulation and injection during lumbosacral transforaminal injections. The rates observe with these two needle types were similar to those we previously observed using Quincke and Chiba needles [15]. Both blunt-tip and pencil-point needles were designed specifically with the goal of improved safety, sacrificing some level of functionality to that end. To date, no in vivo human study has confirmed any improvements in safety during transforaminal epidural injections using these needles. In fact, this study suggests that there is no benefit in regard to the most serious potential complications of this procedure. Catheter-extension needles did reduce the incidence of inadvertent vascular uptake, but their high rates of functional pitfalls limits their potential use in clinical practice.

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