Influence of Volume on the Spread of Local Anesthetic-Methylene Blue Solution After Injection for Intercostal Block

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The purpose of this study was to evaluate the influence of the volume of methylene blue-local anesthetic on the spread of the injectate along the costal pleura. Twenty patients undergoing elective thoracotomy were studied. Twelve patients received intercostal nerve injection with 10 mL of 0.5% bupivacaine with methylene blue (10-mL group), and eight patients received 5 mL of 0.5% bupivacaine with methylene blue (5-mL group). The area of spread of the methylene blue was measured after the pleural cavity was incised. The 10-mL group had a mean area of spread of 51.1 cm^2 as opposed to 17.6 cm^2 for the 5-mL group ($P < 0.05$). In the 10-mL group, eight patients had bupivacaine-methylene blue spread to two intercostal spaces, three patients to three intercostal spaces, and one patient to four intercostal spaces. In the 5-mL group, seven patients had bupivacaine methylene blue spread confined to one intercostal space and one patient to two intercostal spaces. We conclude that a potential anatomic space exists between the costal pleura and the internal intercostal muscle and that the spread of local anesthetic after intercostal nerve block injection is volume dependent.

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Intercostal nerve block with local anesthetic solutions is indicated for reducing pain after thoracotomy and upper abdominal surgery, after rib fracture, and in the treatment of intercostal neuralgia. The block can be achieved by a single injection, multiple injections, and continuous catheter techniques; however, there is controversy with regard to the effect of the technique on spread of the solution. The spread of local anesthetic after intercostal nerve block has been studied in both patients and cadavers (1,2). Although there has been a suggestion that volume may affect the spread of local anesthetic, the comparative volumes have been small (3 and 5 mL) (1,2). There is also the possibility that because of autolysis, spread in the cadaver may be greater than in the patient (3). Spread of local anesthetic cephalad and caudad from the injection site would suggest that a potential anatomic space exists between the costal (parietal) pleura and internal intercostal muscles. This potential space is not identified as such in standard anatomy textbooks (4). A number of recent studies in anatomic specimens and volunteers demonstrated that the spread of the injected solution is confined to one intercostal space (5) or to multiple spaces (6,7). These differences could be related to whether the needle tip is superficial or deep to the internal intercostal muscle. In the present study we sought to evaluate, in live subjects, the relationship between two volumes (5 and 10 mL) of injectate and the spread of local anesthetic mixed with methylene blue after intercostal nerve block. This study attempted to answer two questions. First, can multiple intercostal nerve blocks be achieved with a single injection? Second, does a potential anatomic space exist between the costal pleura and the intercostal muscles?

Methods

After approval by the Indiana University Committee for Protection of Human Subjects and informed patient consent, 20 patients undergoing elective thoracotomy were studied. All patients received general anesthesia consisting of thiopental (4 mg/kg IV) for induction, either vecuronium (0.1 mg/kg IV) or succinylcholine (1.5 mg/kg IV), tracheal intubation, and inhaled isoflurane and nitrous oxide in oxygen. After the initiation of anesthesia, each patient was positioned in the appropriate lateral decubitus position for thoracotomy. Before the surgical incision, 0.5% bupivacaine with methylene blue was injected into the intercostal space two interspaces caudad to the proposed surgical incision. Eight patients received

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Figure 1. Photograph of the costal pleura demonstrating spread of methylene blue across three intercostal spaces after a single intercostal injection with 10 mL of 0.5% bupivacaine with methylene blue. Injection of the solution was performed at the angle of the rib, near the central part of the coloration. The spread of methylene blue was in all directions.

5 mL of bupivacaine with methylene blue, and 12 patients received 10 mL of bupivacaine with methylene blue. The intercostal injection was performed with a 2-in. 22-gauge needle at the posterior angle of the rib 8 cm from the dorsal midline. The needle was directed 45° in the cephalad direction. After the inferior margin of the rib was contacted, the needle was advanced 3 mm beyond the rib. At that point, the needle was fixed and the bupivacaine-methylene blue solution injected. After the intercostal injection, the surgery was begun. After the pleural cavity was exposed, the surgeon (unaware of the volume of injectate) measured the length and width of the spread of the methylene blue. The time from injection to measurement of the area of spread was approximately 30 min. The area of the spread was calculated from the length and width of the stained area. The number of intercostal spaces discolored were counted. Statistical comparisons of the area of spread and the number of intercostal spaces traversed were performed. Statistical analysis used the Wilcoxon signed rank test and two-sample *t*-test. A P value <0.05 was considered significant.

Results

Seven of the eight patients who received 5 mL of bupivacaine-methylene blue had the injectate confined to one intercostal space. Of the 12 patients receiving 10 mL of bupivacaine-methylene blue, eight had spread to two intercostal spaces, three had spread to three intercostal spaces (Figure 1), and one had spread to four intercostal spaces. The patients receiving 10 mL had a mean area of spread of 51.1 ± 19 (SD) cm^2 as opposed to 17.6 ± 7.6 cm^2 ($P < 0.05$) (Table 1). There was no evidence of a preferential medial spread to the paravertebral region. The solution spread medially, laterally, superiorly, and inferiorly from the point of injection.

Table 1. Spread of Local Anesthetic After Intercostal Nerve Block and Area of Staining of Costal Pleura With Methylene Blue

	10-mL Injectate (n = 12)	5-mL Injectate (n = 8)
Width (cm)	6.0 ± 1.5	2.2 ± 1.7
Length (cm)	8.7 ± 1.6	6.9 ± 2.3
Area (cm^2)	51.1 ± 19	17.6 ± 7.6[a]
No. of intercostal spaces	2.4 ± 0.06	1.1 ± 0.03[b]

10 mL Injectate, 10 mL of 0.5% bupivacaine with methylene blue; 5-mL Injectate, 5 mL of 0.5% bupivacaine with methylene blue.
Values are mean ± SD.
[a] $P < 0.05$.
[b] $P < 0.02$.

Discussion

This study demonstrates that the spread of local anesthetic-methylene blue after intercostal injection is volume dependent. In general, a volume of 5 mL is confined to one intercostal space, whereas 10 mL will spread to multiple intercostal spaces.

Other studies have demonstrated some cephalad-caudad spread, but those studies used smaller volumes injected into cadavers. Nunn and Slavin (1) injected 3 mL of India ink into anatomic cadaver preparations and found spread cephalad and caudad involving the intercostal space above and below the injection space. Moore (2) also demonstrated lateral and medial spread after intercostal injection of India ink into cadavers. Moore did not observe cephalad or caudad spread of the dye in most of the specimens. This difference between the studies of Nunn and Slavin (1) and Moore (2) might be explained by size of the needle bevel. A longer bevel is associated with spread of the injectate into more fascial planes. The use of cadavers also introduces the possibility of artificial tissue planes produced by tissue autolysis after death.

In a study of live subjects, Moore et al. (3) injected 5 mL of radiographic dye into the intercostal space and observed spread in all four directions. Mowbray and Wong (8) injected 3 mL of bupivacaine with methylene blue into both patients and cadavers. The solution was confined to one intercostal space in 86% of the patients and 84% of the cadavers. Some of the patients in the Mowbray and Wong study did, however, demonstrate spread to more than one intercostal space. In these studies the actual degree of neural

blockade was not specifically discussed. Studies injecting radiopaque dye with the local anesthetic demonstrated localization to one intercostal space in some patients and spread to multiple intercostal spaces in other patients (6,7). The spread of the dye-local anesthetic solution in our study resembles the spread demonstrated by Crossley and Hosie (6) in a radiologic study. The use of 10 mL of solution in our study produced spread in all directions. There was no preferential medial spread.

Our study demonstrates conclusively that the spread of local anesthetic after intercostal nerve block is volume dependent. Spread in the space between the costal (parietal) pleura and the intercostal muscles depends on proper placement of the needle. The needle should be advanced 3 mm beyond the inferior rib margin to ensure proper deposition of the local anesthetic to facilitate spread. If the needle is too shallow, then the local anesthetic will be confined to one intercostal space. Although our study addresses intercostal spread, the extent of local anesthesia produced was not measured.

Our finding is of clinical significance, because multiple intercostal nerves can possibly be blocked with one injection. This technique can therefore be useful in postoperative analgesia. We have not studied this technique in patients who have a disruption in the parietal pleura (e.g., neoplasm). It is conceivable that in patients with a disrupted pleura, spread of the local anesthetic solution will be restricted. Further clinical studies are warranted in a variety of different clinical situations. A clinical study correlating the degree of intercostal spread with analgesia is also justified. Johnson et al. (9) demonstrated multiple segmental intercostal nerve block by using a continuous catheter technique in the paravertebral region; however, our study addresses the issue when the local anesthetic solution is injected with the conventional single injection technique. The complications associated with intercostal nerve block, such as toxic reactions from rapid absorption of local anesthetics and epinephrine, pneumothorax, and hypotension secondary to paravertebral sympathetic blockade, can occur with any technique. However, a larger volume single injection is not associated with more rapid absorption than multiple injections as long as the total local anesthetic dose is not excessive.

In summary, we have demonstrated that a potential anatomic space does exist between the costal pleura and the internal intercostal muscle and that a local anesthetic-methylene blue solution will spread to multiple intercostal segments. This finding suggests the possibility of achieving multiple intercostal nerve blocks with a single injection of 10 mL of local anesthetic, thereby decreasing the incidence of, or avoiding complications associated with, multiple intercostal injections. Further work in volunteers with this technique is required to determine the number of dermatomes anesthetized.

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