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Continuous thoracic paravertebral nerve blocks in pediatric patients

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CONTINUOUS THORACIC PARAVERTEBRAL NERVE BLOCKS IN PEDIATRIC PATIENTS

By

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SARA BITARAFAN

ABSTRACT

Studies that evaluate the use of ultrasound-guided continuous paravertebral nerve blocks in pediatric patients are scarce, although the use of peripheral nerve blocks has indeed increased in popularity in the adult demographic. The present study aims to describe the epidemiology, safety and efficacy of ultrasound-guided continuous thoracic paravertebral nerve blocks as an everyday practice on a large scale in pediatric patients at a busy, academic, tertiary-care hospital. In all patients studied, a linear ultrasound transducer was used via the transverse in-line technique for catheter placement. Transducer configuration (frequency of oscillation and probe length) was varied based on individual patient factors, such as age, weight and body mass index. A descriptive, retrospective chart review of all patients who received a continuous paravertebral nerve block within a two-year time frame, from 10/2012 to 10/2014, was conducted, resulting in a sample size of 238 paravertebral catheters placed in 214 patients.

In regards to patient demographics, the median age was 2 years (IQR 0.8 years – 12 years), with a range of 1 day to 18 years; and the average weight was 25.3 kg ± 23.6 kg, with a range of 1.8 kg to 113.7 kg. The median catheter duration was 3 days (IQR 2 days – 5 days), with 88.8% of catheters placed unilaterally, and 11.2% placed bilaterally. Median postoperative pain scores, intubation time, morphine equivalent consumption, and midazolam consumption were measured for all patients. The overall complication
rate was 16.8% (n = 36 patients) with a minor catheter complication rate of 16.4% (n = 35). 6.1% (n = 13) of complications were due to catheter leakage, 4.7% (n = 10) due to catheter dislodgement, 2.8% (n = 6) due to skin irritation, 1.9% (n = 4) due to catheter occlusion and 0.9% (n = 2) due to minor bleeding at the site of catheter insertion. Only one patient experienced a major complication (0.5% of total patients), manifested as a self-resolving, 30-second seizure after a bolus administration of 2% chloroprocaine to manage postoperative pain. The patient was bag-mask ventilated for 60 seconds and the catheter was discontinued. No long-term sequelae were present in this case. Lastly, 98.1% (n = 210) of patients experienced sufficient pain coverage, yielding a failed block rate of 1.9% (n = 4).

These results demonstrate safety and efficacy of ultrasound-guided transverse in-line continuous, thoracic paravertebral nerve block in pediatric patients, especially small infants and children. This technique provides an analgesic alternative to the thoracic epidural for postoperative pain treatment in pediatric patients.
# TABLE OF CONTENTS

TITLE PAGE.................................................................................................................. i
COPYRIGHT PAGE........................................................................................................ ii
READER APPROVAL PAGE.......................................................................................... iii
ABSTRACT..................................................................................................................... iv
TABLE OF CONTENTS.................................................................................................. vi
LIST OF TABLES........................................................................................................... vii
LIST OF FIGURES....................................................................................................... viii
LIST OF ABBREVIATIONS......................................................................................... ix
INTRODUCTION ......................................................................................................... 1
METHODS .................................................................................................................... 15
RESULTS ...................................................................................................................... 19
DISCUSSION ................................................................................................................. 25
LIST OF JOURNAL ABBREVIATIONS ................................................................... 30
REFERENCES ............................................................................................................. 31
CURRICULUM VITAE................................................................................................. 33
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epidural block versus Continuous PVNB</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Postoperative Pain Scores</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>Number and Percentage of Intubated Patients per Postoperative Day</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Postoperative Opioid and Sedative Consumption</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Catheter Complication Rate</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Pain Coverage</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Pain Coverage Patient Demographics</td>
<td>24</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thoracic Ultrasound-Guided PVNB</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Median Pain Score</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Postoperative Opioid and Sedative Consumption</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>Catheter Complication Rate</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>Pain Coverage</td>
<td>23</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADARPEF</td>
<td>French-Language Society of Paediatric Anaesthesiologists</td>
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<tr>
<td>AIMS</td>
<td>Anesthesia Information Management System</td>
</tr>
<tr>
<td>BCH</td>
<td>Boston Children’s Hospital</td>
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<tr>
<td>BCH-RAS</td>
<td>Boston Children’s Hospital Regional Anesthesia Service</td>
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<tr>
<td>CSF</td>
<td>Cerebral spinal fluid</td>
</tr>
<tr>
<td>DOS</td>
<td>Day of surgery</td>
</tr>
<tr>
<td>FLACC</td>
<td>Face, Legs, Activity, Cry, Consolability</td>
</tr>
<tr>
<td>GA</td>
<td>General anesthesia</td>
</tr>
<tr>
<td>IICM</td>
<td>Internal intercostal membrane</td>
</tr>
<tr>
<td>IQR</td>
<td>Interquartile Range</td>
</tr>
<tr>
<td>LA</td>
<td>Local anesthesia</td>
</tr>
<tr>
<td>NCA</td>
<td>Nurse-controlled intravenous analgesia</td>
</tr>
<tr>
<td>NRS</td>
<td>Numeric Rating Score</td>
</tr>
<tr>
<td>OR</td>
<td>Operating room</td>
</tr>
<tr>
<td>PCA</td>
<td>Patient/parent-controlled intravenous analgesia</td>
</tr>
<tr>
<td>POD</td>
<td>Postoperative day</td>
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<tr>
<td>PRAN</td>
<td>Pediatric Regional Anesthesia Network</td>
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<tr>
<td>PVNB</td>
<td>Paravertebral Nerve Block</td>
</tr>
<tr>
<td>PVS</td>
<td>Paravertebral Space</td>
</tr>
<tr>
<td>RA</td>
<td>Regional anesthesia</td>
</tr>
<tr>
<td>SEP</td>
<td>Somatosensory Evoked Potential</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analog Scale</td>
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INTRODUCTION

Hugo Sellheim successfully performed the first paravertebral block on laparotomy patients in 1905, when he slowly injected procaine into what is now referred to as the paravertebral space.\(^1\) Regardless of the significant strides made in spinal anesthesia since, the paravertebral nerve block (PVNB) has only gained significant attention in the past couple of decades, owing to its recent surge of interest to Eason and Wyatt, who praised the efficacy and safety of the thoracic paravertebral block, especially in comparison to the more widely acclaimed epidural block, a commonly used type of central neuraxial block.\(^2\) Though originally intended to decimate the adverse side affects associated with various central neuraxial blocks for special surgical procedures, the PVNB has recently been shown to provide adequate pain treatment with a low complication rate in adults during routine surgery and for post-operative pain control.

BACKGROUND

Of the several paravertebral nerve blocks, the lumbar and thoracic PVNB’s are the most widely used. As the name suggests, the lumbar plexus, or psoas compartment block, is used for lower limb pain management.\(^3\) Because a single nerve block may not be sufficient to cover a particular dermatome (a portion of skin supported by a single spinal root) due to the vast number of lower limb nerves, lumbar plexus blocks are frequently performed in concurrence with another nerve block.\(^3\)
On the other hand, the thoracic PVNB is performed for breast, abdomen, chest and rib fracture surgery pain management, by injecting local anesthetic (LA) into the paravertebral space (PVS) in the dorsal region of the body. The PVS is a potential space, wedged in between the heads of the ribs, which lie superiorly and inferiorly. Medial to the PVS lie the vertebral body and intervertebral foramina, whereas the costotransverse ligament is located posteriorly, and the parietal pleura is located anterolaterally. Injection of LA into this space causes specific dermatomes of the thoracic region to be either unilaterally or bilaterally blocked. A single shot of anesthetic can usually block two or three dermatomes at a time. Placement of a catheter during the time of service can help supply a continuous infusion of analgesia during post-operative treatment, thereby managing any resulting pain. Due to their lack of epineurium, the sympathetic nerves that fill the PVS can be easily accessed and affected by the injected local anesthetic. The resulting potent efficacy of local anesthetic in the paravertebral space can then reduce the amount of anesthetic, postoperative analgesia, and supplemental opioids used to achieve the same degree of pain management. By reducing the amount of analgesia administered, any resulting adverse events that could stem from opioid consumption can therefore be avoided. At Boston Children’s Hospital (BCH), the transverse in-line ultrasound-guided technique is used for local anesthetic administration and catheter placement.

In order to visualize Tuohy needle advancement in the transverse, or axial, plane, the New York School of Regional Anesthesia (2013) suggests first placing a high frequency (10-12 MHz) transducer lateral to the transverse process, which is
characterized as a hyperechoic structure with an accompanying acoustic shadow below. The transducer is then moved caudally towards the PVS, a hypoechoic wedge-shaped space, defined posteriorly by the hyperechoic parietal pleura in the corresponding sonographic image, which is displaced downward upon injection of local anesthetic, indicating correct needle tip placement into the PVS.

Traditionally, the landmark technique has been employed, especially in pediatric patients, to administer local anesthetic into the PVS. This is done by simply identifying the transverse spinous process under direct vision with the patient either sitting upright or in the lateral decubitus position (lying on one side). The Tuohy needle is then moved laterally toward the desired PVS. When inserting the needle, a loss-of-resistance can sometimes be felt when the internal intercostal membrane is traversed, which signifies that the needle tip is within the PVS. However, the landmark approach has demonstrated a failure rate of >10% due to the inherent difficulty of needle placement, which is then associated with increased pain, pneumothorax and other more serious complications. With the aid of ultrasound-guidance, the rate of these adverse events has been decreased to nearly 1%, although a greater risk is still associated with bilateral PVNB’s. Thus, the benefit of having sonographic images that accurately display the depth of the PVS, and position of the needle in relation to the PVS and pleural cavity, proves its advantage over the landmark technique.

Additional considerations include aspirating the catheter for blood and/or cerebral spinal fluid (CSF) prior to administration of anesthetic, as well as slow, meticulous, injection of anesthetic to reduce spread, especially into the epidural space. Lastly,
careful insertion and movement of the needle is necessary, even with ultrasound-guidance, to avoid pneumothorax (lung collapse) or pleural puncture.

**Figure 1:** Thoracic Ultrasound-Guided PVNB. A) Transducer positioning in relation to the Tuohy needle; B) corresponding sonographic image where TP = Transverse Process of the vertebral body and PV Space = Paravertebral Space; C) patient in oblique later position where the gray arrow indicates the left scapula, the white arrow indicates the paramedian line and the (> markings represent the spinous processes; D) the needle path to the paravertebral space and the appropriate local anesthetic (LA) spread. Adapted from Vandepitte et al.4

**COMPARATIVE STUDIES**

Generally speaking, the available literature proves that the PVNB is safe and efficacious in adult patients. This has been evaluated by studying postoperative pain scores, opioid consumption, as well as the total duration of catheter placement and
hospital stay. Studies note that with PVNB use, the total opioid consumption can also be reduced, thereby reducing withdrawal symptoms, immunological disruptions, respiratory depression, discomfort, and pain. Although the epidural nerve block has been established as the “go-to” nerve block, recent studies demonstrate comparative analgesic effect between the continuous PVNB, epidural nerve blocks and general anesthesia.

Having a continuous infusion of a local anesthetic, as opposed to a single shot local injection at the time of service, provides pain treatment during the post-operative period, as well as decreased adverse side effects related to anesthesia, such as improved respiration and oxygenation. According to Daly et al., “Thoracic surgery is associated with a 30% reduction in functional residual capacity and 50% reduction in vital capacity, for which uncontrolled postoperative pain is a major contributor.” With the addition of postoperative opioid pain relief, respiratory function is further impaired due to the inherently depressive nature of opioids. The improved respiratory function with continuous PVNB’s has been reflected in spirometry measurements, visual analog scale (VAS) pain scores at rest and during coughing, and blood oxygenation levels. By studying 15 patients with multiple fractured ribs, Karmakar et al. established that continuous PVNB of bupivacainc provides effective analgesia with fewer adverse respiratory and oxygenation side effects, and could therefore be a better alternative to the thoracic epidural.

Recent literature reviews report PVNB’s to have an estimated success rate of 94%, which is significantly higher than the thoracic epidural. This success rate is
manifested in decreased postoperative pain, supplemental postoperative opioid administration, and in some cases, decreased hospital stay.\textsuperscript{9}

**Table 1:** Epidural block versus Continuous PVNB with regards to complications. SEP: somatosensory evoked potential. Adapted from Chelly, 2012.\textsuperscript{6}

<table>
<thead>
<tr>
<th></th>
<th>Epidural</th>
<th>Continuous PVNB</th>
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<tr>
<td>Laterality</td>
<td>Bilateral</td>
<td>As needed</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Frequent</td>
<td>Infrequent</td>
</tr>
<tr>
<td>Postoperative Nausea and Vomiting</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Urinary Retention</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Pruritus</td>
<td>Frequent</td>
<td>No</td>
</tr>
<tr>
<td>Risk of Spinal Cord Injury</td>
<td>Low</td>
<td>Extremely Low</td>
</tr>
<tr>
<td>Risk of Respiratory Depression</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Preservation of Forced Vital Capacity After Thoracotomy</td>
<td>55% of preoperative</td>
<td>75% of preoperative</td>
</tr>
<tr>
<td>Degree of Neural Blockade</td>
<td>Partial (SEPs maintained)</td>
<td>Complete (SEPs ablated)</td>
</tr>
<tr>
<td>Motor Blockade Outside Surgical Dermatomes</td>
<td>Yes</td>
<td>Minimal</td>
</tr>
<tr>
<td>Severity of Bleeding Complications</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Thromboprophylaxis</td>
<td>Complicated</td>
<td>Simple</td>
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Furthermore, a review conducted by Daly et al. asserts that in addition to the fewer adverse side-effects, the PVNB’s simplicity and flexibility with regards to conduction conditions demonstrates its efficiency over the thoracic epidural.\textsuperscript{7} For example, to guarantee safety, thoracic epidural placement is commonly performed with the patient being minimally sedated before induction of anesthesia; however, a PVNB is commonly performed at any point before or after surgery and achieves the same level of safety.\textsuperscript{7} Additionally, a PVNB, as opposed to a thoracic epidural, requires less convoluted and time-consuming routine supervision during the postoperative hospital stay, although
studies have not yet been able to firmly establish that the epidural will yield a longer hospital stay.\textsuperscript{7} Having safe and effective analgesia not only reduces morbidity and improves the recovery rate, but it also lowers overall hospital costs as a result. Additionally, flexibility in anesthetic administration and monitoring makes the PVNB a more desirable approach from a regional analgesia and an anesthesiologist standpoint.

A meta-analysis executed by Scarci et al. that studied the effectiveness of the PVNB across more than 184 articles concluded that the PVNB is at least as effective as the thoracic epidural in terms of analgesia, but with fewer resulting adverse side effects.\textsuperscript{10} This was reflected in a reduced complication rate, lower Visual Analog Scale (VAS) pain scores both at rest and while coughing, better respiratory function, and lower plasma cortisol concentrations indicating less postoperative biological stress.\textsuperscript{10} Likewise, a similar meta-analysis also studied the effectiveness of the PVNB over the thoracic epidural in ten randomized trials.\textsuperscript{11} Paralleling the results uncovered by Scarci et al., this meta-analysis also demonstrated equal analgesic efficacy between thoracic epidurals and PVNB’s manifested in fewer postoperative side effects and a reduced failure and complication rate, but with no significant difference in postoperative pain scores or opioid consumption.\textsuperscript{11} As per usual, postoperative side effects in this case include nausea, vomiting, hypotension, and urinary retention. The reduced contraindications associated with the PVNB certainly question the thoracic epidural’s standing as an intraoperative anesthetic and postoperative analgesic gold standard.

In a prospective, randomized, double blind study that assessed the analgesic differences between thoracic epidurals, both with and without additional hydromorphone
administration, and continuous PVNB, investigators utilized bupivacaine as their form of analgesia for patients undergoing thoracotomies to treat lung cancer.\textsuperscript{12} By assigning patients to three different groups (epidural with bupivacaine alone, epidural with bupivacaine and hydromorphone, and continuous PVNB with bupivacaine alone), Grider et al. were able to evaluate important differences in analgesia in concordance with the type of anesthetic and/or opioid. By comparison of VAS pain scores and incentive spirometer measurements, the group could determine that patients with the epidural infused with both bupivacaine and hydromorphone received better analgesia when compared to patients who received epidurals with bupivacaine alone and patients who received continuous PVNB’s with bupivacaine alone.\textsuperscript{12} The latter two groups received PCA hydromorphone postoperatively to treat pain, and there were no significant differences in the amount of PCA hydromorphone utilized between the two groups.\textsuperscript{12} Nonetheless, the group suggested that a continuous PVNB of a local anesthetic does provide acceptable analgesia, paralleling the results of the two aforementioned meta-analyses.\textsuperscript{12} Finally, this study highlights the potential importance of opioid infusion in addition to the anesthetic, as a way to lessen the rate of the basal infusion, and resulting postoperative treatment.

PVNB’s have also shown superior analgesic advantages when compared to general anesthesia (GA), or extradural infusions. One study demonstrated that out of 20 patients undergoing thoracotomy surgery, only 13\% of those who received a PVNB required postoperative pain treatment, whereas 50\% of patients who received GA required postoperative pain treatment.\textsuperscript{13} In addition to this significant difference in pain
treatment, hospital stay and adverse side-effects associated with anesthesia were greatly reduced in the PVNB group, as opposed to the GA group.\textsuperscript{13} Similarly, a randomized, prospective study investigating 50 patients undergoing Inguinal Hernia repair surgery studied the difference in requisite pain treatment between patients receiving a PVNB and those receiving GA. Patients were randomly assigned to either of the two groups, and researchers found that those who received a PVNB enjoyed a shorter time-to-home readiness and discharge time, in addition to fewer adverse postoperative effects and better overall analgesia.\textsuperscript{14} Thus, similar to the thoracic epidural comparative studies, comparative studies that have assessed analgesic differences between PVNB’s and GA demonstrate significant advantages in favor of the PVNB.

\textbf{THE PEDIATRIC DEMOGRAPHIC}

Although postoperative opioid administration has traditionally been the most common mode of analgesia in pediatric patients, regional anesthesia is frequently used as an adjunct analgesia. Continuous PVNB’s have recently shown promise in providing adequate postoperative pain treatment.\textsuperscript{15} In a prospective, non-comparative study, Karmakar et al. evaluated the safety and efficacy of continuous paravertebral infusions of bupivacaine to treat post-thoracotomy pain in 20 infants.\textsuperscript{15} Practitioners performed the nerve blocks under direct vision, and demonstrated safety without major comorbidities, such as pleural or vascular puncture.\textsuperscript{15} Furthermore, the data demonstrated an overall relatively low median pain score (0.52), with the rare high pain score (measured as a value greater than 3) being a direct result of catheter malfunction.\textsuperscript{15} The study concluded
that a continuous infusion of local anesthetic administered through catheters placed under
direct vision, without ultrasound guidance, is a safe and effective mode to treat
postoperative pain, even in small neonates, with a more favorable side effect profile and
reduced complication and failure rate, especially when compared to other regional
anesthesia (RA) procedures.\textsuperscript{15} Although these pediatric patients had a low complication
and side effect rate, it’s important to note that the majority of failed blocks were
attributed to catheter malfunction. This highlights the need for a more advanced
methodology for catheter production, placement, and postoperative monitoring.

In order to evaluate the safety and efficacy of RA in pediatric patients, in 1996 the
French-Language Society of Paediatric Anaesthesiologists (ADARPEF) conducted a one-
year prospective study using data pooled from multiple institutions.\textsuperscript{16} Ultimately,
researchers found an increased safety rate with peripheral nerve blocks, compared to
central nerve blocks, and have since urged anesthesiologists to utilize peripheral nerve
block techniques with pediatric patients as much as possible.\textsuperscript{16} Twelve years later, the
ADARPEF published a follow-up study to analyze the morbidity and epidemiology of
RA in pediatric patients, compared to GA. Again, the ADARPEF pooled data from
multiple institutions in a one-year prospective study, looking at a total of 47 hospitals
located globally.\textsuperscript{16} Both studies were conducted without the use of ultrasound guidance.
Patients were separated into three groups: GA, GA in concordance with RA, and RA only
(34\% of which were central nerve blocks, including caudal, and 66\% of which were
peripheral nerve block, with a 9\% catheter placement rate across both groups).\textsuperscript{16} Though
the overall complication rate between catheter and non-catheter groups was insignificant,
the complication rate for central neuraxial blocks was seven times higher than the peripheral nerve block complication rate, especially for the youngest patient groups, following in suite of the ADARPEF’s original 1996 study that demonstrated a greater safety and efficacy with the peripheral nerve block.\textsuperscript{16} Furthermore, the ADARPEF’s follow-up study effectively demonstrated a reduced complication rate with RA when compared to GA, and suggested that practitioners should continue to opt for peripheral nerve block, such as the PVNB, whenever appropriate.

Following the ADARPEF’s second study, Polaner et al. sought to accomplish a similar observational, multi-institutional, prospective study to evaluate the safety and efficacy of RA for pediatric patients, utilizing a more rigorous auditing system so as to yield more accurate and precise data.\textsuperscript{17} Pooling data from across various U.S. hospitals into a central database, the Pediatric Regional Anesthesia Network (PRAN), researchers were able to record the type of anesthesia and the technique utilizing, as well as any corresponding complications across a total of 14,917 nerve blocks performed on 13,725 pediatric patients.\textsuperscript{17} With a greater focus on comparing and contrasting continuous (catheter) nerve blocks with single-shot nerve blocks, in addition to an acknowledgement of ultrasound guidance, the PRAN data were able to shed light on more up-to-date considerations with regard to common analgesic practices, and therefore a broader goal of large-scale quality improvement. Most relevant to the discussion was the finding that 43\% of recorded complications were a direct result of the catheter, most common being postoperative malfunctions (i.e. kinked or dislodged), with 9\% of complications corresponded to a completely failed nerve block.\textsuperscript{17} As a result, researchers assert the high
priority need for better catheter placement methods so as to reduce this relatively high complication rate.\textsuperscript{17} Paralleling the ADARPEF study, investigators noted an increase in peripheral nerve blocks in pediatrics, attributing the increase to the increased utilization of ultrasound guidance.\textsuperscript{17} Most importantly, the PRAN study reaffirmed that RA is a safe mode of anesthesia and analgesia in pediatric patients due to its relatively low complication rate.\textsuperscript{17}

Indeed, the use of ultrasound guidance, which in and of itself is attributed to increased safety and efficacy of block placement, has corresponded to a dramatic shift from central neuraxial blocks to peripheral nerve blocks as a commonplace procedure in pediatric anesthesia. On the onset of continuous PVNB popularity, the nerve block was traditionally used for special case procedures. For example, to evaluate the efficacy of the bilateral thoracic PVNB under ultrasound guidance, 30 Nuss procedure pediatric patients were enrolled in a prospective, comparative, observer-blind study at the West China Hospital of Sichuan University.\textsuperscript{18} By measuring postoperative complication rates, pain scores (via the Face, Legs, Activity, Cry, Consolability (FLACC) scale for patients under 7 years of age and VAS for patients over 7 years of age), total opioid consumption, and attempts at the PCA pump, the group was able to compare the efficacy and safety of continuous infusions of bilateral thoracic PVNB’s performed under ultrasound guidance with a control group that was only given postoperative opioids for pain management.\textsuperscript{18} The need for this study stemmed from the negative side effect profile associated with postoperative systemic opioid administration, which includes, respiratory depression, nausea, vomiting, oxygen desaturation, and negative behavioral changes.\textsuperscript{18} Postoperative
negative behavioral changes, a direct result of unmanaged pain, is specifically prevalent in the pediatric demographic, observed to last up to several months after surgery, and include increased anxiety, bedwetting, nightmares, and eating disorders.\textsuperscript{18} Ultimately, Qi et al. determined that continuous, thoracic, bilateral PVNB’s are indeed more effective at managing postoperative pain than intravenous opioid administration, noting the decreased pain scores, complication rate and negative behavioral changes in the experimental group.\textsuperscript{18} Furthermore, researchers suggested that ultrasound guidance may be a prominent contributor to the growing success of PVNB placement, and resulting safety and efficacy of its analgesic properties.\textsuperscript{18} Nonetheless, a larger study is necessary to reaffirm this notion.

One of the more recent studies to describe the continuous PVNB catheter placed under ultrasound guidance evaluated 22 pediatric patients retrospectively, from 6 months and 6 kg to 17 years and 135 kg.\textsuperscript{19} Boretsky et al. found that ultrasound guided PVNB catheter placement via an in-line technique yielded low FLACC and Numeric Rating Score (NRS) pain scores four days postop, reduced postoperative opioid consumption two days postop, and no recorded complications.\textsuperscript{19} These results affirm the safety and efficacy of thoracic PVNB catheter placement under ultrasound guidance in infants and children. Lastly, this study employs the same PVNB catheter placement methodology and research methodology as the currently described study.
OBJECTIVES

Though the literature concerning large sample evaluations of regional anesthesia use in pediatric patients is comprehensive, the evidence concerning the efficacy and safety of ultrasound guided PVNB for thoraco-abdominal surgery is scarce, with limited data from studies with small sample sizes. Because the development of new technologies and high frequency ultrasound guidance has shown promise in the scant number of studies available, data from larger-scale studies is warranted.

Therefore, the principal purpose of this study is to describe the use and epidemiology of ultrasound guided, continuous paravertebral nerve blocks at the Boston Children’s Hospital – a busy, academic, pediatric, tertiary-care institution – via descriptive, retrospective chart review. The goal is to demonstrate safety and efficacy of the paravertebral nerve block by assessing postoperative pain scores, total supplemental opioid consumption, and documentation of any procedural complications.
METHODS

All pediatric patients (≤18 years of age) who underwent a paravertebral nerve block placement at Boston Children’s Hospital from October 2012 to October 2014 were included in the study, yielding a sample size of 238 paravertebral catheters placed in 214 pediatric patients within a two-year time span. For all cases evaluated, a linear transducer was used with variability in frequency in oscillation and length based on patient age, weight and body mass index (BMI).

CATHETER INSERTION METHODOLOGY

Patients receiving a unilateral PVNB were positioned laterally, so that the operative side was facing up, while patients receiving a bilateral PVNB were positioned full prone, with the face down. Bilateral PVNB patients could have also been positioned laterally initially, with the shoulders arched, making a 45-degree angle with the operation bed, exposing both sides of the patient’s back. After having the relevant thoracic level marked via the landmark technique, the patient was then prepped and draped in preparation for the needle insertion. As previously stated, ultrasound probe configuration was determined based on individual age, weight and BMI patient characteristics. This study followed an identical methodology for probe configuration as Boretsky et al.’s study:

“For patients <5 years or under 18 kg, a 2.5-cm linear transducer oscillating at 6-13 MHz was used (SonoSite L25x; Bothell, WA, USA). For patients over 5 years of age and with a BMI <30, a 5-cm linear probe oscillating at 6-15 MHz was used (SonoSite HFL50x). For the patients with a BMI >30, a 3.8-cm linear probe oscillating at 5-10 MHz was used (SonoSite L38xi). The
ultrasound was sheathed in a sterile fashion and placed in a transverse orientation over the midline of the back at the designated dermatome level… Probe length was chosen to allow flat contact with the surface of the patient’s back and to ensure adequate depth to visualize the pleura while optimizing clarity of structures. On patients with high BMI a lower frequency probe was needed because of the increased depth from the skin to paravertebral space. In some of the obese patients, the IICM could not be visualized and the needle was advanced until it was just above the pleura.

Once the transverse spinal process was identified and a 5 or 10cm, 18 gauge Tuohy needle that was advancing medially, breached the internal intercostal membrane (IICM), a few milliliters (mL) of saline were injected into the potential wedge-shaped space between the parietal pleura and transverse process’ acoustic shadow, which would identify correct needle placement in the PVS. Saline was used in an attempt to minimize the systemic concentration of local anesthetic in patients. Negative aspiration for blood and/or CSF was then conducted, and 0.5 ml/kg of 0.5% ropivacaine was injected on each side, if appropriate, totaling up to a maximum 15 mL of local anesthetic per block. Next, a single-orifice catheter (B. Braun Medical Inc., Bethlehem, PA, USA) was advanced 2-3 cm past the needle tip. Correct catheter placement was confirmed by additional normal saline injection, viewed as a displacement of the pleura on the corresponding sonographic image. This process was then repeated on the other side if the patient was receiving a bilateral nerve block, and catheters were finally held and protected with clear adhesive.

The Regional Anesthesia Team introduced infusions of LA either in the operating room (OR) or the PACU, using a total of 0.5 mg/kg/hr 0.2% ropivacaine, with a maximum dose of 12mL/hr per block, for patients weighing greater than 50 kg. For patients weighing less than 50 kg, either 0.1% or 0.2% ropivacaine was used, achieving the same total dose of 0.5 mg/kg/hr. If a patient received a bilateral thoracic PVNB, the
total anesthetic dose was divided equally between the two catheters. During the postoperative hospital stay, the Pediatric Acute Pain Treatment Service would examine patients twice per day, and adjusted pain treatment if necessary. The Perioperative Pain Team made note of all post-operative data in Notegen, a password-protected IT-supported software, including all adverse events, clinical effectiveness measures, side effects, and all noteworthy incidents.

**DATA COLLECTION METHODOLOGY**

During the six-month data collection period, the BCH Regional Anesthesia Service (BCH-RAS) data were collected from individual electronic medical records, with a primary focus on extracting data from SurgiNet, which includes automated electronic medical record documentation, and Notegen, which includes data recorded postoperatively by the Pediatric Acute Pain Treatment Service. Using patient medical record numbers, AIMS and Notegen were used to extract data regarding the patient age, weight, type of PVNB used (either unilateral or bilateral), date of service, duration of catheter insertion, VAS, NRS and FLACC pain scores, total intubation time, total postoperative opioid consumption and any significant post-operative incidents and/or complications. The appropriate data were collected up to five days after the date of operation and service, and were recorded in a password-protected Excel spreadsheet with anonymous patient identifiers. Though the NRS and FLACC scales are VAS scales, the FLACC pain scale was used for children 7 years or younger, while the NRS pain scale
was used for children older than 7 years of age. Opioid consumption data was converted to median morphine equivalents consumed per day prior to analysis. Furthermore, due to the particular nature of the patient demographic, the data were not normally distributed, and as such, are depicted, for the most part, as median values and interquartile ranges.
RESULTS

Of the 238 continuous paravertebral nerve blocks that were placed in 214 patients to manage pain for various thoraco-abdominal surgeries, 88.8% were bilateral and 11.2% were unilateral. Patients ranged from 1-day-old to 18 years of age, with a median of 2 years (IQR 0.8 years – 12 years) and an average age of 6.1 years ± 6.4 years. Patients also ranged from 1.8kg to 113.7 kg, with an average weight of 25.3 kg ± 23.6 kg, and a median weight of 13.2 kg (IQR 7.6 kg – 41 kg). Finally the median duration of catheter insertion was 3 days (IQR 2 days – 5 days). Tables 2 – 7 show additional study results.

Table 2: Postoperative Pain Scores. POD = Postoperative Day

<table>
<thead>
<tr>
<th>VAS/NRS/FLACC Pain Score</th>
<th>POD 1</th>
<th>POD 2</th>
<th>POD 3</th>
<th>POD 4</th>
<th>POD 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2</td>
<td>1.9</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>0.4 – 3.1</td>
<td>0.5 – 3.4</td>
<td>0.2 – 2.8</td>
<td>0 – 2.3</td>
<td>0 – 2.3</td>
</tr>
</tbody>
</table>
Figure 2: Median pain score over five postoperative days

Table 3: Number and Percentage of Intubated Patients per Postoperative Day

<table>
<thead>
<tr>
<th></th>
<th>POD 1</th>
<th>POD 2</th>
<th>POD 3</th>
<th>POD 4</th>
<th>POD 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>74</td>
<td>65</td>
<td>62</td>
<td>57</td>
<td>51</td>
</tr>
<tr>
<td>Percentage of Total Patients</td>
<td>34.6%</td>
<td>30.4%</td>
<td>29.0%</td>
<td>26.6%</td>
<td>23.8%</td>
</tr>
</tbody>
</table>

The average intubated time was 3.5 days ± 8.3 days, with a median of 0 days (IQR 0 – 4 days), and a range of 0 days to 75 days.

Table 4: Postoperative Opioid and Sedative Consumption

<table>
<thead>
<tr>
<th>Opioid (mg/kg/day)</th>
<th>DOS</th>
<th>POD 1</th>
<th>POD 2</th>
<th>POD 3</th>
<th>POD 4</th>
<th>POD 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine Equivalent Median</td>
<td>0.16</td>
<td>0.2</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Morphine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equivalent IQR</td>
<td>0.05 – 1.45</td>
<td>0.05 – 2.04</td>
<td>0 – 1.73</td>
<td>0 – 1.63</td>
<td>0 – 1.56</td>
<td>0 – 0.68</td>
</tr>
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<td>-------------</td>
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<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Midazolam Median</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Midazolam IQR</td>
<td>0 – 1.2</td>
<td>0 – 1.5</td>
<td>0 – 0.15</td>
<td>0 – 0.05</td>
<td>0 – 0.03</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 3**: Postoperative Opioid and Sedative Consumption. Eq. = Equivalent. The red box shows the morphine equivalent 50th percentile with error bars ranging from the lower 25th percentile, or first interquartile, to the 75th percentile, or third interquartile. Thus, the interquartile range is graphically represented for both morphine equivalent values and midazolam values in mg/kg/day. The orange error bars represent the 75th percentile of midazolam per postoperative day. Because the median and first IQR are both zero, only the 3rd IQR, or 75th percentile, could be graphed.

The total range of morphine equivalent consumption was 0 mg/kg/day to 133.4 mg/kg/day, and the total range of midazolam consumption was 0 mg/kg/day to 47.04 mg/kg/day.
Table 5: Catheter Complication Rate

<table>
<thead>
<tr>
<th>Catheter Complication</th>
<th>Number of Patients</th>
<th>Percentage of Total Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dislodgement</td>
<td>10</td>
<td>4.7</td>
</tr>
<tr>
<td>Occlusion</td>
<td>4</td>
<td>1.9</td>
</tr>
<tr>
<td>Leakage</td>
<td>13</td>
<td>6.1</td>
</tr>
<tr>
<td>Skin Irritation</td>
<td>6</td>
<td>2.8</td>
</tr>
<tr>
<td>Minor Bleeding</td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td>Total Complications</td>
<td>35</td>
<td>16.4</td>
</tr>
</tbody>
</table>

Figure 4: Catheter Complication Rate

Catheter complications were measured against the total number of patients who received a continuous PVNB, as opposed to the total number of catheters placed. The only major complication (0.5% of total patients) that occurred involved a 1ml/kg bolus
injection of 2% chloroprocaine via catheter in a 9.4 kg, 1-year-old patient in order to manage pain on postoperative (POD) 1. The analgesic infusion resulted in a 30-second seizure, while the patient was bag-mask ventilated for 60 seconds. The catheter was promptly discontinued, and the patient recovered after 5 minutes. No long-term sequelae ensued. Thus, the total complication rate, both major and minor, is 16.8%.

**Table 6: Pain Coverage**

<table>
<thead>
<tr>
<th>Pain Control</th>
<th>Sufficient</th>
<th>Insufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>210</td>
<td>4</td>
</tr>
<tr>
<td>Percentage of Total Patients</td>
<td>98.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Figure 5: Pain Coverage**
No instances of insufficient pain coverage were due to catheter malfunctions.
DISCUSSION

So far, there have been limited data describing the use of the continuous PVNB in the pediatric population. The underlying study is the largest scale data collection evaluating the safety and efficacy of continuous PVNB’s in pediatric patients, especially neonates and small children. This study demonstrates that the continuous, thoracic PVNB is a valid analgesic alternative to the thoracic epidural, with few associated adverse side effects and complications.

Looking at the patient demographics, it’s clear that the majority of patients studied were very young. The median age of 2 years (IQR 0.8 years – 12 years), in addition to a median weight of 13.2 kg (IQR 7.6 kg – 41 kg), naturally focuses the study on infants and small children. Furthermore, the duration of catheter insertion was 3 days (IQR 2 days – 5 days), focusing the time frame of the study to five days after the date of service.

PAIN SCORES

Due to the study’s focus on infants and small children, it should be no surprise that a good number of patients were therefore intubated for a substantial amount of time postoperatively, which is reflected in the average intubation time of 3.5 days ± 8.3 days. This partially explains the low median pain scores throughout the five postoperative days evaluated, since many patients were intubated and paralyzed. Sedated and intubated infants were evaluated for pain mainly by heart rate, blood pressure and respiratory rate,
all of which would increase if the patient experienced any pain. Additionally, opioids were titrated to patient comfort, if necessary. If any discomfort were to be presented, the patient would immediately receive a supplemental infusion of narcotics and sedatives to manage pain, further explaining the low median pain scores. The IQR’s increased around POD 2, which suggest that a greater number of patients experienced an increase in pain. This could be due to catheter malfunction or reduced efficacy of the analgesia. Usually if the catheter proved ineffective, blocked, kinked, or dislodged, it was simply removed, and postoperative pain was then treated with opioids. Often, the plan for many patients would be to discontinue the catheter after three days or less, which explains the median catheter duration of 3. Any subsequent pain would also be managed by opioids and sedatives until the patient felt comfortable.

**OPIOID CONSUMPTION**

All analgesic drugs were converted to morphine equivalents to evaluate total analgesia administration. Midazolam, a benzodiazepine and sedative, was also administered to alleviate pain and discomfort. Thus, total midazolam consumption was also calculated. Following the same trend as the median postoperative pain scores, the range of opioid consumption increased between postoperative days one and two. This increase could be due to the discontinuation of analgesic infusion and subsequent catheter removal. Regardless, narcotics were titrated to comfort for all patients upon observance of pain, resulting in the low median analgesia and sedative consumption per day.
Representing the amount of analgesia in mg/kg per postoperative day, the median morphine equivalent consumption, though initially low, continued to drop to zero by the third postoperative day (see Figure 3). The top end of the 50th percentile (red box) represents the median morphine equivalent consumption. Similarly, representing the amount of sedative consumption in mg/kg per postoperative day, the median midazolam amount was zero for every postoperative day, including the date of surgery (DOS). Because of the low medians, only the IQR could be graphically represented. However, large ranges of opioid administration were recorded for both sets of opioids. This is due to the inherent nature of the studied demographic – while neonates required very little opioids for pain management, older children generally required much more, a result of both size and individual patient factors. Nonetheless, both analgesia and sedative consumption were low for each postoperative day, as reflected in the respective medians per postoperative day. These data demonstrate the efficacy of the continuous PVNB for the management of postoperative pain.

**CATHETER COMPLICATION RATE**

We were able to demonstrate safety with the continuous PVNB due to a complication rate of 16.8%. Catheter malfunctions were the primary cause of minor complications, and the only major complication resulted from a 2% chloroprocaine administration, which could arguably be independent of the continuous PVNB, and rather, dependent on individual patient factors. Among the minor catheter complications, the primary catheter malfunction was catheter leakage, followed by catheter
dislodgement and skin irritation. Again, a usual reaction to catheter malfunction was discontinuation of the catheter, and administration of opioids to manage pain. Nonetheless, the rate of minor complications is relatively low, proving the continuous, thoracic PVNB to be a safe anesthetic and analgesic technique. Furthermore, the pain coverage data also affirms that the majority of patients (98.1%) in the sample received sufficient postoperative analgesia.

**SUMMARY**

Due to the low pain scores, low supplemental opioid consumption, relatively low complication and failure rate, this study demonstrates safety with and efficacy of the transverse in-line ultrasound-guided continuous thoracic paravertebral nerve block in pediatric patients, especially infants and small children. Furthermore, the continuous, thoracic paravertebral nerve block has demonstrated comparative analgesia to the thoracic epidural, but with a more favorable side effect profile.

Limitations to this study most notably include inconsistent medical record documentation within individual patient records and across patient records. This inconsistent documentation calls for a high priority need to develop a standard documentation practice, and a more vigilant attention to meticulous documentation, so as to avoid inexact retrospective data collection, and in attempt to work towards the greater goal of quality improvement. Additionally, the retrospective and non-comparative nature of the study is also a limitation.
Other steps that can be taken towards quality improvement include a study assessing the pharmacokinetics of local anesthetic. As of now, the optimal dosing regimen and toxicity levels for pediatric patients have not been established. Furthermore, a study comparing the pharmacokinetics of different local anesthetics could also prove beneficial. Additionally, the prominent contribution of catheter malfunctions to the rate of minor complications in this study, calls for a re-evaluation of catheter placement technique. An advanced methodology in this field could greatly improve the quality of pain treatment. Lastly, a large, randomized, prospective, double-blinded, comparative study should be conducted to evaluate the safety and efficacy of ultrasound-guided, continuous, thoracic PVNB’s compared to other regional anesthesia techniques, to determine more established alternatives to traditional modes of anesthesia and postoperative pain treatment.
## LIST OF JOURNAL ABBREVIATIONS

<table>
<thead>
<tr>
<th>Journal Abbreviation</th>
<th>Full Title</th>
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<tbody>
<tr>
<td>Anesth. Analg.</td>
<td>Anesthesia &amp; Analgesia</td>
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<tr>
<td>Br. J. Anaesth.</td>
<td>British Journal of Anaesthesia</td>
</tr>
<tr>
<td>Curr. Opin. Anaesthesiol.</td>
<td>Current Opinion in Anaesthesiology</td>
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<tr>
<td>J. Anesth.</td>
<td>Journal of Anesthesia</td>
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<tr>
<td>N. Y. Sch. Reg. Anesth.</td>
<td>New York School of Regional Anesthesia</td>
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<tr>
<td>Pediatr. Anesth.</td>
<td>Pediatric Anesthesia</td>
</tr>
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</table>
REFERENCES


CURRICULUM VITAE

SARA BITARAFAN
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EDUCATION

Boston University
Master of Science in Medical Science
Boston, MA
Expected May 2015

Dartmouth College
Bachelor of Arts in Psychology
Hanover, NH
June 2013

Harvard University
Transfer Term – Organic Chemistry
Cambridge, MA
Summer 2010

La Jolla Country Day School
La Jolla, CA
June 2009

WORK EXPERIENCE

Boston Children’s Hospital
Clinical Research Assistant and Intern; July 2013 - Present
• Studying the effectiveness and safety of paravertebral nerve blocks in pediatric patients
• Employed part-time, collecting and analyzing data for over 200 patients
• Working as an OR Anesthesia Technician, assisting anesthesiologists with surgical preparations and turn-overs

Boston Medical Center
bWell Center Volunteer; July – December 2013
• Provide pediatric patients and respective families with free health education and resources
• Integrate various multi-media with costumer service to support families and increase patient satisfaction
• Collaborate with Boston community partnerships to foster multi-dimensional health and wellness culture

The National Student Leadership Conference
Head Team Advisor on Medicine and Healthcare; Summer 2013
• Managed staff dynamic and facilitated Team Advisors in their leadership of high school students
• Worked directly with program and site directors to organize and implement daily activities
• Assumed the same responsibilities as a Team Advisor
  Team Advisor on Medicine and Healthcare; Summer 2012
• Taught academic and leadership sessions, as well as mediated small group discussions and debriefings

ClearView Eye and Laser Medical Center  San Diego, CA
Shadowing and Clinical Research Intern; August – September 2012
• Studied the effectiveness of Collagen Cross-Linking laser procedure on treating Keratoconus for 30 patients
• Shadowed optometric technicians and ophthalmologists with patient appointments and LASIK surgery

The Scripps Research Institute  La Jolla, CA
Biochemical Research Intern; December 2011 – March 2012
• Worked forty hours per week, assisting and shadowing scientists with lab work and research
• Trained to manipulate bacteria, DNA, and protein product control at a basic level

VA San Diego Healthcare System  La Jolla, CA
Nurse’s Assistant; July – September 2008
• Volunteered with nurses’ duties throughout the pre-operational and post-operational ward of hospital
• Aided in taking patient vitals, examining patient health, and cleaning patient rooms

LEADERSHIP ACTIVITIES

North Country Weekend Program  Hanover, NH
Co-Chair; Winter 2010 – Spring 2013
• Organized and executed a three-day event every three months, while managing a budget of $500
• Mentored fifteen to twenty inter-city Boston high school students via various educational workshops, focusing on the college application process, financial management, and college life

Dartmouth Women’s Club Water Polo Team  Hanover, NH
Interim Coach; Fall 2012
• Voted Interim Coach in 2012 and led 2012 pre-season training, six hours per week
• 2012 and 2011 New England Champions, and ranked 7th nationally
• Practiced twelve hours per week and competed in four annual tournaments as a team member, 2009-2012