Perspective

Robotic thoracic surgery in children and adolescents—technology and adaptability

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Abstract: The advent of robotic surgery has ushered in new and exciting innovations in all aspects of thoracic surgery—from mediastinal procedures to esophageal and lung cancer operations. While the bulk of robotic thoracic surgery today is performed on adult patients, the robotic platform also offers opportunity to provide minimally-invasive procedures to selected pediatric patients. In this article we will review the most common robotic thoracic surgical operations that are appropriate for pediatric patients.

Keywords: Robotic surgical procedures; thoracic surgical procedures; pediatrics; lung; robotics

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Robotic surgery for pediatric patients has been described since at least 2001 (1), and the robotic platform has been increasingly used in pediatric gastrointestinal, genitourinary, and solid tumor resections (2,3). However, the number of pediatric minimally-invasive thoracic procedures utilizing the robotic platform remains smaller versus other surgical subspecialty procedures (4). The robot is not suitable for most children that are 2 years of age or younger due to their diminutive size and smaller rib interspaces. Other factors influencing the utilization of the robotic platform in pediatric thoracic surgery include: (I) smaller chest walls in children limiting port placement and access, (II) hesitancy to adapt new technology to a delicate patient cohort, and (III) the overall cost of the robotic system (5). Perhaps the most significant reason is the training of the typical pediatric surgeon, which has in the past been commonly devoid of robust robotic training in general surgical residency. This is also coupled with the fact that in most academic institutions, pediatric thoracic operations are performed by pediatric surgeons and not thoracic surgeons, who may be more familiar with the robotic platform. More commonly the expertise of the two subspecialties are combined.

With careful patient selection, a supportive robotic and pediatric surgical team, and a detailed understanding of thoracic anatomy and physiology, the da Vinci® robotic platform (Intuitive Surgical Inc., Sunnyvale, CA, USA) can be easily adapted to fit selected pediatric patients.

The pediatric thoracic procedures we have found to be most ideal for adaptation to the robotic platform include thymectomy (6), pulmonary sequestration resection and pulmonary metastasectomy. We have now performed 293 pediatric thoracic operations of which approximately 115 are robotic. *Figure 1* illustrates the da Vinci® Xi port placement for a robotic thymectomy in a 10-year-old adolescent with myasthenia gravis. In general, we prefer to use the da Vinci® Si robot that it has 5-mm ports (an advantage in smaller pediatric patients) whereas the newer Xi robot has only 8 mm and larger ports.

We believe that a pediatric patient's height is a surrogate for chest wall circumference and therefore the robotic platform should be appropriate even for children under three feet (91 cm) tall. We do not have a strict exclusionary height criteria for our pediatric patients. There are case reports describing smaller patients—even infants and neonates (7) however this may be more appropriate for abdominal operations such as genitourinary and general surgical procedures where abdominal insufflation creates more space for port clearance. In these smaller patients or newborns, we have used, similar to others (4), a video-assisted platform or (if required) thoracotomy and a cervical incision for procedures such as sliding tracheoplasty.

We have performed the vast majority of our elective

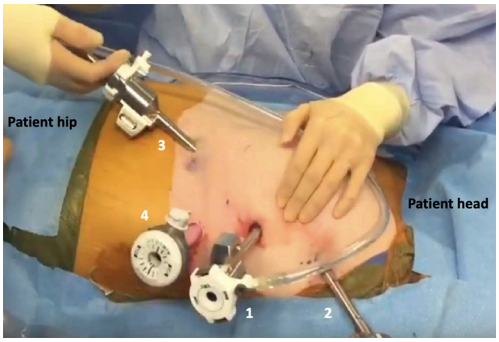

Figure 1 Robotic port placement for adolescent thymectomy. This figure illustrates port placement for the da Vinci® Xi robotic system on a 10-year-old girl who underwent left-sided robotic thymectomy for myasthenia gravis. The ports are labeled in the order they are placed. The assistant's hand is covering the patient's left breast. Port sizes are listed as follows: port 1 =12 mm, port 2 =8 mm, port 3 =8 mm, port 4 =8 mm previously, but now we have downsized to a 7-mm port with a 5-mm internal width. A video of the proper and thoughtful port placement as well as the conduct of a pediatric robotic left-sided thymectomy can be found here: https://www.youtube.com/watch?v=smfsWMBxf6M&t=2s.

pediatric operations during the summer months in order to mitigate or eliminate time out of school. The optimal operative timing needs to be carefully considered in the pediatric patient cohort. Robotic pulmonary resections usually only require two weeks or less for full recovery unlike more complex procedures such as congenital heart operations. In general, children recover quicker than most adults and are able to resume full physical activity in 2–3 weeks after robotic thoracic surgery.

We have performed many robotic operations in children. The most common operations we have performed are: lobectomy for sequestration, segmentectomy and/or wedge resection for metastatic disease (more commonly though we use a video-assisted platform for wedge resection), lobectomy for larger tumors, thymectomy (most commonly for myasthenia gravis), resection of esophageal duplication cysts, removal of neurilemoma/schwannoma, and others. These operations are exceedingly safe and effective. We have experienced no conversions, no blood transfusions, a median hospital length of stay of 1 day (range, 0–5 days), avoidance of the pediatric intensive care unit, and most importantly, no 30- or 90-day mortalities (8).

In conclusion, we believe that the robotic platform provides a safe and effective minimally-invasive platform for selected pediatric patients and surgical teams. The earlier outcomes have been spectacular in our experience. A video of the proper and thoughtful port placement as well as the conduct of a pediatric robotic left-sided thymectomy can be found here: https://www.youtube.com/watch?v=smfsWMBxf6M&t=2s.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in studies involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was taken from all individual participants.

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