Paediatric robotic surgery

A review of the current status of robotic surgery use in paediatrics

Joshua Cave CT1, Chelsea and Westminster NHS Foundation Trust

Simon Clarke Consultant Paediatric Surgeon, Chelsea and Westminster NHS Foundation Trust

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Paediatric robotic surgery offers unique challenges within this rapidly advancing field. The financial costs forproviding this advanced technology are significant for what are essentially low-volume complex cases. There has been a slow rate of uptake within most paediatric surgical centres around the world.due to both to finance as well difficulties associated with equipment primarily designed for adults. Consequently there has been a slow rate of uptake within most paediatric surgical centres around the world. The ergonomics required for the da Vinci® master–slave-type platform currently challenge the small working space in very small children. Only two centres in the UK currently offer robotic surgery for children.* This article aims to review the current state of robotics within the field of paediatric surgery and surgical subspecialties.

Paediatric urology

Urology has arguably seen the greatest uptake of robotic surgery within paediatrics. One of the first uses of robotics in children was a (dismembered Hynes-Anderson) pyeloplasty for pelviureteric junction obstruction (PUJO), because the ureterico-pelvic anastomosis was a significant technical challenge using conventional laparoscopic surgery.[1]

Robotic-assisted pyeloplasty (RAP)

A meta-analysis of RAP in 2014 examined 12 retrospective studies comparing open pyeloplasty (OP) with RAP and laparoscopic pyeloplasty (LP) with RAP.[2] Darzi's group found a tendency towards better RAP success rates in comparison with LP; although when compared with OP, RAP was equivalent. There was no difference in rates of re-operation and complications between groups. However, OP was statistically significantly faster and cheaper than RAP – although it resulted in a significantly longer hospital stay (+1 day). The studies included were limited by retrospective technique, variable methods of group selection and inconsistent comparison of outcomes, which limit their own conclusions. Subsequent to this, two large multi-centre comparison of OP, LP and RAP[3,4] support Cundy's findings that RAP demonstrated a high success rate and resulted in a

significantly shorter hospital stay.[3,4] There was also some evidence that there is a lower rate of complication amongst RAP. However, Chan *et al*'s larger study found no difference in rates of complications.

Ureteral re-implantation[5]

The standard operative approach for ureteral re-implantation is via an open approach,[5] although there is some evidence of comparable success in RAUR. Kasturi *et al* achieved VUR resolution with a robotic approach in 99.3% of cases[6] and this has been supported in a comparison study finding equivalence of RAUR (97%) with open technique (100%),[7] as well as in a case matched series that also examined an intra-vesical technique.[8] Marchini *et al* conclude that there is no significant difference in postoperative complications; however, it is worth noting all significant complications – urinary retention, bladder leak and ureteral leak are within the robotic arm of their comparison. A higher rate of bladder spasm and haematuria in the open group account for an overall finding of no difference in complication rates.[8] One RAUR was readmitted with a ureteric leak.[6] In line with other minimally invasive surgery, there does appear to be a reduced length of stay and postoperative pain.[7,9]

Ureteroureterostomy

Ureteroureterostomy is performed in a number of indications as the primary procedure (duplex systems with an upper pole ectopic ureter, obstructed ureterocele, etc) and there are several case series reporting successful robotic-assisted ureteroureterostomy.[10–12] Most recently, a small comparison of robotic-assisted ureteroureterostomy with open ureteroureterostomy concluded: 'Operative times and complication rates were comparable with slightly shorter length of hospitalisation in robotic cases.'[13]

Mitrofanoff and reconstructive bladder surgery

The appendicovesicostomy (Mitrofanoff) has been established as feasible to perform with robotic assistance by a number of case series and in 2015 Grimsby *et al* compared the open and robotic approaches. They found no difference in rates of complication (26% *vs* 29%); however, the severity of complications in the robotic group was clinically greater 7.6% (Clavien>3). Furthermore, rates of continence were just 90% when compared with 97% in the open group.[14] Similar results are seen in larger multi-centre study of reconstructive surgeries involving Mitrofanoff.[15] Grimsby *et al* attribute these issues to technical adaptation of the operation to robotic platform. Other complex reconstructive surgery has also been examined in a useful, small comparison of open and robotic bladder augmentation (and associated procedures) by Murphy *et al*, who found similar functional outcomes and rates of complication but with significantly reduced length of stay.[16]

Miscellaneous

Paediatric urology procedures without a reconstructive element have adapted well to traditional laparoscopic approach; nevertheless, there is extensive literature documenting the use of robotics in hemi-nephrectomy[17] and nephroureterectomy.[18] Those surgeries that must access the pelvis and therefore have a narrow field may well suit a robotic approach. Indeed, there are reports of robotic-assisted excision of bladder diverticulum,[19] urachal cyst excision,[20] excision of posterior urethral diverticulae,[21] prostatic utricles,[22] seminal vesicle cyst,[23] and varicocele.[24]

Paediatric general surgery

As in adult surgery, inguinal hernia repairs are commonplace in paediatrics, although they are performed usually through a smaller open inguinal incision. The paediatric laparoscopic hernia repair is also far less involved than its adult counterpart and does not use a mesh, making robotic assistance an unnecessary technical addition in its current format. Other more complex procedures have been carried out robotically.

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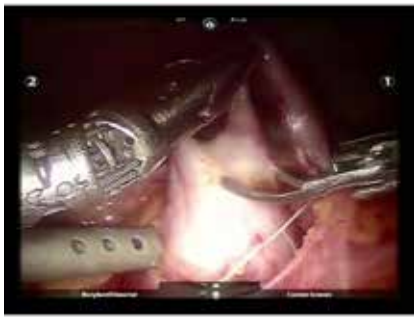
Fundoplication

A meta-analysis in 2014 reporting outcomes of 297 children[25] found that despite a tendency towards conversion to open surgery in the laparoscopic fundoplication (LF) group (6.1% *vs* 3%), there was no significant difference in postoperative complications (RF 8.9% *vs* 8% LF) found. In one study the most common complication in the RF and LF was a tight wrap, requiring dilatation (8% and 6%), whereas in the open series

Figure 1 Paediatric robotic procedure

Figure 2 Robotic pyeloplasty (Courtesy of Nisha Rahman, Chelsea and Westminster NHS Foundation Trust)



wound infections were more common (4%). The meta-analysis was limited as most studies were retrospective with non-synchronous selection of controls, but perhaps most significantly limited by their absence of long-term follow-up of success.

Hepatobiliary surgery

HPB surgery in children inevitably involves intricate and demanding MIS procedures. Choledochal cyst excision and reconstructive Roux-en-Y hepaticoenterostomy are technically complex and, with the exception of centres in South East Asia,[26] open procedures are still relatively prevalent. The laparoscopic technique often involves extending the umbilical incision to allow extra-corporeal anastomosis. Meehan *et al* describe a robotic approach outlining how additional degrees of freedom offered by the robot conferred a real advantage;[27] a view shared by others with experience in the area.[28] This approach has also been repeated in small infants (<10kg) (although they use an extracorporeal anastomosis)[29] and by the same group in a larger series;[30] within this series they converted 19% of their cases, although only 1 patient had any complications. A similar rate of conversion is also seen in another case series,[31] which also used extracorporeal anastomosis for the Roux-en-Y loop. Recent evidence,[32] however, suggests that laparoscopic Kasai portoenterostomies may have significantly worse outcomes than an open approach. This may reduce enthusiasm for further robotic work.

Miscellaneous

Robotic-assisted cholecystectomies and splenectomies are relatively prevalent in the literature.[33–38] However, all authors emphasise that – although these are useful training opportunities in the robot platform – neither robotic-assisted splenectomy nor cholecystectomy seem to offer additional benefit over the laparoscopic approach. Indeed, there is no comparative research in the field.

There are also case reports and series that document a diverse array of successful robotic general and gynaecological surgery such as robotic-assisted diaphragmatic hernia repair,[39,40] Heller's cardiomyotomy for achalasia,[41,42] duodenojejunostomy for SMA syndrome,[43] repair of duodenal atresia,[44] anorectal pull-through for anorectal malformations,[38] ovarian cystectomies and salpingo/oophorectomies.[45] Further study is needed to assess whether these procedures are indeed effective and whether they confer any benefit above traditional minimally invasive surgery (MIS).

Paediatric cardiothoracic surgery

Cardiac

The surgical interruption of a patent ductus arteriosus (PDA) in robot-assisted thoracoscopic surgery (RATS) *vs* video-assisted thoracoscopic surgery (VATS) has been described.[46] The authors, however, concluded that the VATS procedure is relatively straightforward and that no advantage is offered by RATS, especially allowing for increased complexity of setup and cost.[46] One study since examined robotic cardiac surgery specifically in children,[47] involving the division of congenital vascular rings, and found RATS comparable but did not offer further advantage over VATS.

Mediastinal

RATS has limited further examination in current literature. The largest series reports on 11 cases including mediastinal cyst excision, diaphragmatic hernia repair, Heller's myotomy, oesophagoplasty and oesophageal atresia repair via RATS.[48] There were several conversions to open surgery in neonatal patients.[48] The small neonatal thorax represents the greatest obstacle in adapting the large 5 or 8mm instruments of most robotic platforms into paediatric surgery, and the authors conclude that RATS seems only appropriate in patients with a weight >20kg.

Paediatric oncological surgery

Despite widespread use of MIS in adult oncological surgery and in non-oncological paediatric surgery, open surgery is the usual standard of care for resection of paediatric solid tumours. Paediatric oncological MIS and robotic assistance is a relatively recent development that is lacking high-level evidence,[49,50] although there is a wide range of case literature.

Thoracic

Anecdotally, the robot seems well adapted to intricate mediastinal dissection and has been used in the excision of left ventricular myxoma[51] and removal of complex massive oesophageal leiomyoma.[52] There is support for the robot's applicability to the mediastinum in a larger case series.[53] There is also a relatively large case series that demonstrated in neurogenic chest tumours: 'Resection [R0] can be as complete as an open procedure without having to complicate the operative technique in the same operating time.' And the authors felt that 'the surgeon has a better visualisation of the tumour and its anatomic connections'.[54]

Abdominal

There are mostly individual case reports for robotic-assisted abdominal oncological surgery in children. Excision of juvenile cystic adenomyoma,[55] a radical cystoprostatectomy,[55] partial nephrectomy for RCC,[57] retroperitoneal lymph node dissection[58] and partial adrenalectomy for pheochromocytoma.[59] A common theme discussed by many of the authors is of the suitability of the robotic approach to extended lymph node dissection; indeed, one asserts that 'vision was excellent throughout the procedure, which is very important during dissection and not always the case during open surgery.'[56] The solitary case series supports these claims and the authors experienced no complications and achieved R^0 resection in all.[60]

There is some dispute as to whether the fundamental oncological principles of no tumour spillage and total resection of tumour margins can be adhered to by robotic-assisted surgery; a specific concern being the lack of haptics having an impact on the surgeon's ability to differentiate cancerous from healthy tissue. However, it has been noted that 'the loss of tactile feedback is, in our opinion, very well compensated for by the excellent optical system'.[56] Cancer patients are necessarily followed up for recurrence and only prospective long-term studies of robot resections can give assurances of robotic adherence to oncological principles.

Paediatric neurosurgery

Computer technology has long been used in neurosurgery, specifically in 'image-guided' surgery and surgical planning. This has been applied to robotics in the form of the robotised stereotactic assistant ('ROSA').[61] Robotic-assisted paediatric neurosurgical procedures are sparsely reported, although there is a recent large case series of an array of procedures, making up 128 cases. The authors demonstrated a high rate of success (97.7%) and low rate of complications (3.9%) and no incidences of permanent neurological deficit.[61] Such results in a diverse case series is encouraging for the safety and utility of robotic assisted paediatric neurosurgery. Indeed, as is noted in previous case reports, 'precision of movement millimetre resolution make robotic tools highly attractive in the treatment of intracranial lesions'.[62]

The future of robotics in paediatric surgery

With advancing technology and the demand for more compact robotic platforms, the future for robotic surgery will no doubt result in a reduction of instrument size and an improvement in haptic feedback. This puts the paediatric patient – in particular, the newborn – at the forefront. Reconstructive surgery such as oesophageal and intestinal anastomosis, all of which require a delicate and more magnified approach will benefit enormously from these advances. The financial restraints that exist in public health systems currently restrict the advancement and training of many in robotics. With a more expanded competitive market, this should improve the landscape but in the interim the paediatric and neonatal patient must be at the forefront of research into the future of robotic surgery.

*Leeds General Infirmary and Chelsea and Westminster Healthcare NHS Foundation Trust.

References

1. Peters CA. Robotically assisted paediatric pyeloplasty: Cutting edge or expensive toy? *BJU International* 2004; **94(9):** 1,214–1,215.
2. Cundy TP, Harling L, Hughes-Hallett A *et al.* Meta-analysis of robot-assisted vs conventional laparoscopic and open pyeloplasty in children. *BJU International* 2014; **114(4):** 582–594.
3. Silay MS, Spinoit AF, Undre S *et al.* Global minimally invasive pyeloplasty study in children: Results from the Pediatric Urology Expert Group of the European Association of Urology Young Academic Urologists working party. *J Pediatr Urol* 2016; **12(4).**
4. Chan YY, Durbin-Johnson B, Sturm RM, Kurzrock EA. Outcomes after pediatric open, laparoscopic, and robotic pyeloplasty at academic institutions. *J Pediatr Urol* 2017; **13(1).**
5. Jodal U, Smellie JM, Lax H, Hoyer PF. Ten-year results of randomized treatment of children with severe vesicoureteral reflux. Final report of the International Reflux Study in Children. *Pediatr Nephrol* 2006; **21(6):** 785–792.
6. Kasturi S, Sehgal SS, Christman MS *et al.* Prospective long-term analysis of nerve-sparing extravesical robotic-assisted laparoscopic ureteral reimplantation. *Urology* 2012; **79(3):** 680–683.
7. Smith RP, Oliver JL, Peters CA. Pediatric robotic extravesical ureteral reimplantation: comparison with open surgery. *Journal of Urology* 2011; **185(5):** 1,876–1,881.
8. Marchini GS, Hong YK, Minnillo BJ *et al.* Robotic assisted laparoscopic ureteral reimplantation in children: case matched comparative study with open surgical approach. *Journal of Urology* 2011; **185(5):** 1,870–1,875.
9. Harel M, Herbst KW, Silvis R *et al.* Objective pain assessment after ureteral reimplantation: Comparison of open versus robotic approach. *J Pediatr Urol* 2015; **11(2).**
10. Bansal D, Cost NG, Bean CM *et al.* Infant robot-assisted laparoscopic upper urinary tract reconstructive surgery. *J Pediatr Urol* 2014; **10(5):** 869–874.
11. Leavitt DA, Rambachan A, Haberman K, DeMarco R *et al.* Robot-assisted laparoscopic ipsilateral ureteroureterostomy for ectopic ureters in children: description of technique. *J Endourol* 2012; **26(10):** 1,279–1,283.
12. Yee DS, Shanberg AM. Robotic-assisted laparoscopic ureteroureterostomy in an adolescent with an obstructed upper pole system and crossed renal ectopia with fusion. *Urology* 2006; **68(3):** 673.e5–7.
13. Lee NG, Corbett ST, Cobb K *et al.* Bi-institutional comparison of robot-assisted laparoscopic versus open ureteroureterostomy in the pediatric population. *J Endourol* 2015; **29(11):** 1,237–1,241.
14. Grimsby GM, Jacobs MA, Gargollo PC. Comparison of complications of robot-assisted laparoscopic and open appendicovesicostomy in children. *Journal of Urology* 2015; **194(3):** 772–776.
15. Gundeti MS, Petravick ME, Pariser JJ *et al.* A multi-institutional study of perioperative and functional outcomes for pediatric robotic-assisted laparoscopic Mitrofanoff appendicovesicostomy. *J Paedr Urol* 2016; **12(6).**
16. Murthy P, Cohn JA, Selig RB, Gundeti MS. Robot-assisted laparoscopic augmentation ileocystoplasty and mitrofanoff appendicovesicostomy in children: updated interim results. *European Urology* 2015; **68(6):** 1,069–1,075.
17. Herz D, DaJusta D, Ching C, McLeod D. Segmental arterial mapping during pediatric robot-assisted laparoscopic heminephrectomy: A descriptive series. *J Pediatr Urol* 2016; **12(4):** 266.e1–6.
18. Bansal D, Cost NG, Bean CM *et al.* Comparison of pediatric robotic-assisted laparoscopic nephroureterectomy and laparoendoscopic single-site nephroureterectomy. *Urology* 2014; **83(2):** 438–442.
19. Christman MS, Casale P. Robot-assisted bladder diverticulectomy in the pediatric population. *J Endourol* 2012; **26(10):** 1,296–1,300.
20. Rivera M, Granberg CF, Tollefson MK. Robotic-assisted laparoscopic surgery of urachal anomalies: a single-center experience. *J Laparoendosc Adv Surg Tech A* 2015; **25(4):** 291–294.
21. Alsowayan O, Almodhen F, Alshammari A. Minimally invasive surgical approach to treat posterior urethral diverticulum. *Urol Ann* 2015; **7(2):** 273–276.
22. Goruppi I, Avolio L, Romano P *et al.* Robotic-assisted surgery for excision of an enlarged prostatic utricle. *Int J Surg Case Rep* 2015; **10:** 94–96.
23. Moore CD, Erhard MJ, Dahm P. Robot-assisted excision of seminal vesicle cyst associated with ipsilateral renal agenesis. *J Endourol* 2007; **21(7):** 776–779.
24. Hidalgo-Tamola J, Sorensen MD, Bice JB, Lendvay TS. Pediatric robot-assisted laparoscopic varicocelectomy. *J Endourol* 2009; **23(8):** 1,297–1,300.
25. Cundy TP, Harling L, Marcus HJ *et al.* Meta analysis of robot-assisted versus conventional laparoscopic fundoplication in children. *Journal of Pediatric Surgery* 2014; **49(4):** 646–652.
26. Liem NT, Pham HD, Dung LA *et al.* Early and intermediate outcomes of laparoscopic surgery for choledochal cysts with 400 patients. *J Laparoendosc Adv Surg Tech A* 2012; **22(6):** 599–603.
27. Meehan JJ, Elliott S, Sandler A. The robotic approach to complex hepatobiliary anomalies in children: preliminary report. *J Pediatr Surg* 2007; **42(12):** 2,110–2,114.
28. Woo R, Le D, Albanese CT, Kim SS. Robot-assisted laparoscopic resection of a type I choledochal cyst in a child. *J Laparoendosc Adv Surg Tech A* 2006; **16(2):** 179–183.
29. Dawrant MJ, Najmaldin AS, Alizai NK. Robot-assisted resection of choledochal cysts and hepaticojejunostomy in children less than 10 kg. *J Pediatr Surg* 2010; **45(12):** 2,364–2,368.
30. Alizai NK, Dawrant MJ, Najmaldin AS. Robot-assisted resection of choledochal cysts and hepaticojejunostomy in children. *Pediatr Surg Int* 2014; **30(3):** 291–294.
31. Chang EY, Hong YJ, Chang HK *et al.* Lessons and tips from the experience of pediatric robotic choledochal cyst resection. *J Laparoendosc Adv Surg Tech A* 2012; **22(6):** 609–614.
32. Hussain MH, Alizai N, Patel B. Outcomes of laparoscopic Kasai portoenterostomy for biliary atresia: A systematic review. *Journal of Pediatric Surgery* 2017; **52(2):** 264–267.
33. Cundy TP, Shetty K, Clark *et al.* The first decade of robotic surgery in children. *Journal of Pediatric Surgery* 2013; **48(4):** 858–865.
34. Mahida JB, Cooper JN, Herz D *et al.* Utilization and costs associated with robotic surgery in children. *Journal of Surgical Research* 2015; **199(1):** 169–176.
35. Meehan JJ, Sandler A. Pediatric robotic surgery: A single-institutional review of the first 100 consecutive cases. *Surgical Endoscopy and Other Interventional Techniques* 2008; **22(1):** 177–182.
36. Klein MD, Langenburg SE, Lelli JL *et al.* Pediatric robotic surgery: Lessons from a

clinical experience. *J Laparoendosc Adv Surg Tech A* 2007; **17(2):** 265–271.
37. Alqahtani A, Albassam A, Zamakhshary M *et al.* Robot-assisted pediatric surgery: how far can we go? *World Journal of Surgery* 2010; **34(5):** 975–978.
38. Al-Bassam A. Robotic-assisted surgery in children: advantages and limitations. *J Robot Surg* 2010; **4(1):** 19–22.
39. Meehan JJ, Sandler A. Robotic repair of a Bochdalek congenital diaphragmatic hernia in a small neonate: robotic advantages and limitations. *J Pediatr Surg* 2007; **42(10):** 1,757–1,760.
40. Meehan JJ, Torres JE. Robotic repair of Morgagni congenital diaphragmatic hernia in an infant. *J Robot Surg.* 2008;**2(2):97-9.**
41. Chaer RA, Jacobsen G, Elli F, Harris J, Goldstein A, Horgan S. Robotic-assisted laparoscopic pediatric Heller's cardiomyotomy: initial case report. *J Laparoendosc Adv Surg Tech A.* 2004;**14(5):270-3.**
42. Altokhais T, Mandora H, Al-Qahtani A, Al-Bassam A. Robot-assisted Heller's myotomy for achalasia in children. *Comput Assist Surg* 2016; **21(1):** 127–131.
43. Bütter A, Jayaraman S, Schlachta C. Robotic duodenojejunostomy for superior mesenteric artery syndrome in a teenager. *J Robot Surg* 2010; **4(4):** 265–269.
44. Meehan JJ. Robotic repair of congenital duodenal atresia: a case report. *J Pediatr Surg* 2007; **42(7):** E31–3.
45. Nakib G, Calcaterra V, Scorletti F *et al.* Robotic assisted surgery in pediatric gynecology: promising innovation in mini invasive surgical procedures. *J Pediatr Adolesc Gynecol* 2013; **26(1):** e5–7.
46. Le Bret E, Papadatos S, Folliguet T *et al.* Interruption of patent ductus arteriosus in children: Robotically assisted versus videothoracoscopic surgery. *Journal of Thoracic and Cardiovascular Surgery* 2002; **123(5):** 973–976.
47. Mihaljevic T, Cannon JW, del Nido PJ. Robotically assisted division of a vascular ring in children. *Journal of Thoracic and Cardiovascular Surgery* 2003; **125(5):** 1,163–1,164.
48. Ballouhey Q, Villemagne T, Cros J *et al.* Assessment of paediatric thoracic robotic surgery. *Interactive Cardiovascular and Thoracic Surgery* 2015; **20(3):** 300–303.
49. van Dalen EC, de Lijster MS, Leijssen LGJ *et al. Minimally invasive surgery versus open surgery for the treatment of solid abdominal and thoracic neoplasms in children. Cochrane Database of Systematic Reviews* 2015(1).
50. Chan KW, Lee KH, Tam YH, Yeung CK. Minimal invasive surgery in pediatric solid tumors. *J Laparoendosc Adv Surg Tech A* 2007; **17(6):** 817–820.
51. Hassan M, Smith JM. Robotic assisted excision of a left ventricular myxoma. *Interactive Cardiovascular and Thoracic Surgery* 2012; **14(1):** 113–114.
52. DeUgarte DA, Teitelbaum D, Hirschl RB, Geiger JD. Robotic extirpation of complex massive esophageal leiomyoma. *J Laparoendosc Adv Surg Tech A* 2008; **18(2):** 286–289.
53. Meehan JJ, Sandler AD. Robotic resection of mediastinal masses in children. *J Laparoendosc Adv Surg Tech A* 2008; **18(1):** 114–119.
54. Lacreuse I, Valla JS, de Lagausie P *et al.* Thoracoscopic resection of neurogenic tumors in children. *Journal of Pediatric Surgery* 2007; **42(10):** 1,725–1,728.
55. Akar ME, Leezer KH, Yalcinkaya TM. Robot-assisted laparoscopic management of a case with juvenile cystic adenomyoma. *Fertility and Sterility* 2010; **94(3):** E55–E6.
56. Anderberg M, Backman T, Annerstedt M. Robot-assisted radical cystoprostatectomy in a small child with rhabdomyosarcoma: a case report. *J Robot Surg* 2008; **2(2):** 101–103.
57. Cost NG, Geller JI, DeFoor WR *et al.* A robotic-assisted laparoscopic approach for pediatric renal cell carcinoma allows for both nephron-sparing surgery and extended lymph node dissection. *Journal of Pediatric Surgery* 2012; **47(10):** 1,946–1,950.
58. Cost NG, DaJusta DG, Granberg CF *et al.* Robot-assisted laparoscopic retroperitoneal lymph node dissection in an adolescent population. *Journal of Endourology* 2012; **26(6):** 635–640.
59. Rogers CG, Blatt AM, Miles GE *et al.* Concurrent robotic partial adrenalectomy and extra-adrenal pheochromocytoma resection in a pediatric patient with von Hippel-Lindau disease. *Journal of Endourology* 2008; **22(7):** 1,501–1,503.
60. Meignan P, Ballouhey Q, Lejeune J *et al.* Robotic-assisted laparoscopic surgery for pediatric tumors: a bicenter experience. *J Robot Surg* 2017.
61. De Benedictis A, Trezza A, Carai A *et al.* Robot-assisted procedures in pediatric neurosurgery. *Neurosurgical Focus* 2017; **42(5).**
62. Vougioukas VI, Hubbe U, Hochmuth A *et al.* Perspectives and limitations of image-guided neurosurgery in pediatric patients. *Childs Nervous System* 2003;**19(12):** 783–791.