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Robot assisted pediatric surgery: review of comparative studies focusing on complications

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Abstract. Robotic surgery, has had a progressive development also in the pediatric field. The aim of this report is to revise the existing pediatric literature focusing on the incidence of complications in robot-assisted surgery (RAS) compared to conventional minimally invasive surgery (MIS) and open approaches. We selected comparative studies published in Pubmed database. We found 6 studies comparing RAS to MIS fundoplication, 1 study comparing robotic and open treatment of choledocal cyst, 1 study comparing robotic and laparoscopic partial splenectomy, 10 comparing RAS and open pyeloplasty, 6 comparing RAS and MIS pyeloplasty, 2 comparing RAS and MIS nephrectomy, 4 comparing RAS and open ureteral reimplantation, 1 comparing RAS and MIS ureteroureterostomy, 1 comparing RAS and MISsplenectomy. The best OCEBM (Oxford Centre for Evidence Based Medicine) level was 3. Current data in the literature do not demonstrate a clear advantage of robotic surgery over other existing techniques.

Keywords. Robotic surgery, minimally invasive surgery, fundoplication,choledocal cyst

Introduction

Robotic surgery, has had a progressive development also in the pediatric field mainly due to the advantages it offers compared to traditional laparoscopy: 3D vision, better precision of movement, comfort for the surgeon. On the other hand, it shows high costs that limit its function.

Nevertheless, a strong evidence that this technique is advantageous to the patient, still lacks.

The purpose of this report is to revise the existing pediatric literature focusing on the comparative studies between robot-assisted technique and conventional laparoscopy and open surgery and assess the incidence of complications.

Material and Methods

We searched in the PubMed database the following keywords: "robot", "robotic surgery", "robot-assisted", "da Vinci" and "computer-enhanced surgery" combined with "child", "children", "infants "and" pediatric ".

We selected publications in English belonging to the category of comparative studies and reviews published in the last 5 years giving relevance to the most recent ones.

Data regarding author, number of patients, intraoperative and postoperative complications were extracted.

Results of literature review

32 comparative studies and 9 reviews fulfilled the following criteria: involved pediatric patients, compared robot-assisted surgery (RAS) with conventional minimally invasive surgery (MIS) or open techniques.

We found 6 studies comparing RAS and MIS Fundoplication, 1 study comparing robotic and open treatment of choledocal cyst, 1 study comparing robotic and laparoscopic partial splenectomy, 10 comparing RAS and open pyeloplasty, 6comparing RAS and MIS pyeloplasty, 2 comparing RAS and MIS nephrectomy, 4 comparing RAS and open ureteral reimplantation,1 comparing RAS and MIS ureteroureterostomy, 1 comparing RAS and MISsplenectomy. The best OCEBM level was 3.

Abdominal Surgery

Fundoplication

6 comparative studies [1-6] and 4 systematic reviews [7-10] were found comparing robot assisted surgery to open or laparoscopic fundoplication.

The results are summarized in table 1.

Two of these studies [1,2] were reported to the IPEG's meeting, 4 studies were published in scientific journals, and the 4 reviews analyzed the above-mentioned studies.

In 2004, Ivascu et al [1] reported their experience with 17 cases treated by RAS and 34 by MIS. They didn't report complications.

Antao et al [2] reported their results during the IPEG meeting in 2010 concluding they found no difference in term of intra/postoperative complications. They had a recurrence in the robotic group and 3 in the laparoscopic group.

Lahert [3] in 2006 compared 10 prospective cases treated by RAS and 10 retrospective controls treated by MIS. They had not complications. Anderberg et al [4] used the same method comparing 14 robotic cases to 10 laparoscopic cases. They experimented 2 complications in the robotic group and one in the laparoscopic group. Copeland in 2008 [5] and Al-Bassam in 2009 [6] compared respectively 50 RAS cases and 50 MIS cases and 25 RAS cases with 25 MIS cases concluding they had no difference in term of complications.

The reviews available [7-10] summarized the results of these 6 comparative studies. The details of the complications of the available comparative studies are reported in table 2.

Choledocal cyst

Only one comparative study regarding robotic treatment of choledocal cyst was found. Kim et al [11] compared 36 cases of RAS to 42 cases of open surgery. They had 5 complications in the robotic group and 1 complication in the open group, but the difference wasn't statistically significative (reported p value: 0,090).

Splenectomy

Vasilescu et al [12] reported their experience comparing 10 RAS cases to 22 laparoscopic cases of subtotal splenectomy in hereditary spherocytosis. They found no difference in term of complications.

Urology

Pyeloplasty

Robot assisted Pyeloplasty versus open Pyeloplasty

10 studies [13-22] and 3 reviews [10, 23, 24] were found comparing open and robotic pyeloplasty. The details are summarized in table 3. Yee and colleagues [13] compared the results of 8 cases treated with the robotic approach to 8 cases treated with open technique. The authors reported 1 case of ileus and 1 case of mechanical failure in the robotic group and a case of the UPJ stenosis in the open group. The statistical analysis did not demonstrate a significant difference.

Lee et al [14] analyzed the results of 33 patients in each group and they reported a worsening in hydronephrosis in one case of the robotic group requiring redo. Sorensen [15] in 2011 described 5 complications in the robotic group: 4 urinary leakages (1 of them requiring nephrostomy and 1 requiring stent placement) and 1 gross hematuria treated conservatively. He also described 3 mechanical failures of the robotic system. In the open group he had 3 complications (dehydration, stent migration and pyelonephritis) treated conservatively.

Dangle [17] reported 1 omental incarceration in the port site requiring open repair in the robotic group. Barbosa et al [18] compared 58 cases of robotic pyeloplasty to 154 cases of open pyeloplasty and he found 1 worsening of hydronephrosis in the robotic group requiring redo and 6 complications in the open group, 3 of them requiring redo procedures.Bansal [19] in 2014 described 3 complications in the robotic group (3/9 cases): 1 urinary leak requiring nephrostomy, 1 ileus and 1 UTI. In the open group he had 4 complications, 1 of them requiring nephrostomy for obstruction. Sukumar et al [20] and Varda et al [21] described respectively a complication rate of 12% and 8% in the robotic group and of 9,6% and 6,8% in the open group. Further details regarding the kind of complication are missed.

Finally Behan et al [16] and Liu et al [22] reported their experience comparing open and robotic pyeloplasty, but no details regarding complications are mentioned in their studies. The 3 reviews analyzed the above-mentioned studies.

Robot assisted pyeloplasty versus laparoscopic pyeloplasty

We found 6 comparative studies [25-30] and 4 reviews [10, 31-33] on robot-assisted and laparoscopicpyeloplasty. The details are summarized in table 4.

Franco et al. [25] in 2007compared 12 cases of RAS to 15 cases of laparoscopic pyeloplasty. They reported 1 leakage for 7 days postoperatively and a mechanical failure in the robotic group and 2 leakage for 4 and 5 days respectively in the laparoscopic group. Kim et al [26] reported no post-operative complications in the robotic group (84 patients) and 2 complications in the laparoscopic group (54 patients): 1 infection and 1 urinary leakage. Subotic el al. [27] reported their experience comparing 19 patients treated robotically and 20 treated laparoscopically. They had 1 mechanical intraoperative failure and 6 postoperative complications in the robotic group: 1 port-site omentum prolapse, which was reduced under anesthesia, 1 case of macrohematuria, 1 stent displacement (these 2 last patients, required stent removal earlier than planned), 2 urinary tract infections treated successfully with antibiotics, 1 anastomotic leakage, which resolved spontaneously. In the laparoscopic group there have been 5 complications: 2 stent displacements requiring replacement in 1 case and temporary nephrostomy in the other; 1 worsening of hydronephrosis requiring temporary nephrostomy and 2 UTI treated with antibiotics. Capsule et al [28] didn't report the complication rate of their series. Riachy et al. [29] described 1 intraoperative accidental liver puncture treated conservatively and one stent displacement requiring percutaneous nephrostomy in the laparoscopic group and 2 urinary leakage treated conservatively in the robotic group. Ganpule et al [30] in 2015 had 1 persistent hydronephrosis in each group requiring nephrectomy and 1 mechanical failure requiring conversion to laparoscopy in the robotic group.

Nephrectomy

2 comparative studies and 1 review were found regarding nephrectomy. Bansal et al [34] in 2014 compared robotic approach to the laparoendoscopic single site (LESS) one. They found 1 urinary retention and 1 urinary leakage in the robotic group and 1 umbilical abscess in the LESS group.

Kim et al [35] in 2012 analyzed the nephrectomy option in children comparing open (39), transperitoneal laparoscopic (11), LESS (11) and robotic (11) approaches. They didn't report data regarding complications. These data are summarized in table 5.

Ureteral reimplantation

We found 4 studies [36-39] and 1 review [9] comparing robotic and open ureteral reimplantation.

Sorensen et al. [36] reported no intraoperative complications in both groups. The robotic group was treated by extravesical (EV) approach and open group by intravesical (IV) approach. Regarding the postoperative complications they described 1 case of ureteral obstruction and 1 case of urinoma in the robotic group both requiring ureteral stenting and 1 case of readimission for dehydration, 1 case of recurrent pyelonephritis and 1 case of Pseudomonas wound infection in the open group.

Smith el al [37] compared 25 cases for each group. Also in this study the IV approach was used in the robotic group and the EV one in the open group. The authors reported 3 cases of UTI in the robotic group and one leakage in the open one. Marchini et al. [38] differentiated IV and EV approach in both groups. Regarding the intravesical approach they reported 5 complications in the robotic group (1 urinary retention and 4 bladder leak requiring double j stenting for 2 to 4 weeks) and 12 cases of hematuria in open group. Regarding the extravesical approach, the authors reported 4 cases of urinary retention in the robotic group and 2 cases of hematuria in the open group.Schomburg et al. [39] compared 20 cases for each group treated

with extravesical approach. They reported 2 Clavien III level complication in the robotic group and 4 Clavien I-II level complications in the open group, no details regarding the latter is reported. The complications reported in these studies are summarized in table 6.

Ureteroureterostomy

Lee et al [40] compared 25 robot-assisted ureteroureterostomy to 19 open ones. They found 1 UTI in the first group and 3 complications in the open group: 1 UTI, 1 case of recurrent non febrile UTI and 1 postoperative UVJO requiring nephrostomy. No Further studies regarding this topic were found.

Appendicovescicostomy

We found only 1 comparative study regarding appendicovesicostomy. Grimsby et al. [41] included 28 open and 39 robotic appendicovesicostomies in their study. In the robotic group there have been 10 complications: 2 wound infections, 3 hospital readmission, 2 febrile UTI, 3 bowel obstructions. In the open group there have been 8 complications: 1 wound infection, 2 hospital readmission, 2 febrile UTI, 1 Clostridium Difficile infections, 1 peritonitis and 1 foot drop, no Clavien III level complications were found.

Discussion

Robotic surgery is progressively developing even in children. Despite the advantages already described, this technology is highly expensive and is further limited by the patient size in pediatric age.

Currently in literature, there is a plethora of experiences, case report and case series on the safety and feasibility of surgical procedures usually performed with minimally invasive techniques in children. We can say (may affirm) that all procedures feasible in MIS, have already been described as also feasible with robotic approach. The reverse is likewise true: there is currently not a routine for which the robot is indispensable. The real advantage that this approach can lead to the patient has not yet been firmly established.

Although there are numerous reports of pediatric robotic surgery, comparative studies are still few (32) and have a low level of evidence (at the highest level 3). Most of the existing studies are based on small series and among the conclusions are not reported statistically significant differences in terms of complications and outcomes.

One wonders if the rate of complications between the various approaches is really similar or if the results are affected by the small number of patients involved. We analyze below the results of comparative studies in terms of complications for various procedures.

In *fundoplication* studies, the overall frequency of complication was 8,9% in robotic group and 8% in the laparoscopic group. Cundy, [33] in a meta-analysis of 2014 report a forest plot underlying there is no significant difference between the two groups in terms of frequency of complications (OR=1. 13; 95% CI=0, 47-2,70; p=0, 78).

In a recent the meta-analysis on *pyeloplasty*, Chang [24] reported a higher risk of complications in the robotic approach when compared to the open one (RR=1. 29, 95%CI 1.05-1.58, p=0, 001). These data are discordant with those of a previous review, however, where the sample was smaller and did not include the more recent studies. All the available studies comparing robotic and laparoscopic pyeloplasty concluded that there is not a significant difference in complication rate. Similar conclusions are reported in the comparative

studies and reviews on nephrectomy and ureteral reimplantation and in the single studies on choledocal cyst, partial splenectomy, ureteroureterostomy and appendicovesicostomy respectively.

A point of discussion may be the fact that not all studies reported in detail the complications so, they can't be classified according to ClavienDindo levels and therefore, despite the complication rate is numerically similar, it could be significative as regards the complications' severity.

Some trials [13,15,25,27,30] reported mechanical failures among the intraoperative complications. Unfortunately, there are no accurate data on the incidence of this type of complications in pediatric surgery, however Alemzadeh and Coll. [42] recently described the results derived by the MAUDE database of these untoward effects in adult robotic surgery.

The authors found 10,624 adverse events with a total of 1,745,000 robotic procedures performed; 9377 of these events were caused by malfunction. The mechanical failures were believed responsible for 63.5% of patient injuries reported in the study and for 5/144 deaths. Although rare, complications due to malfunctions can occur, so they should be taken into account.

Conclusion

Current data in the literature do not demonstrate a clear advantage of robotic surgery over other existing techniques. In most of the studies, the comparison between the complications does not reach statistical significance. Unfortunately the available literature does not exceed the OCEBM level 3.

The complexity of robotics technology exposes the operators to the risk of malfunction, which, though low, must be taken into account. In the majority of cases the major adverse events have not a single cause, but are derived from a chain of events that can be prevented and stopped.

Table 1. Comparative study and reviews on fundoplication

Author	Study	Robot	Lap	Technique
Ivascu, 2004	RCCS	17	34	Nissen
Lehert 2006	Prospective cases, retrospective controls	10	10	Thal
Copeland 2008	RCCS	50	50	Nissen
Al-Bassam 2009	RCS	25	25	Nissen
Anderberg 2009	Prospective cases, retrospective controls	14	10	Nissen
Antao 2010	RCS	19	33	Nissen
Hambraeus 2013	Systematic Reviews of the above-mentioned studies			
Cundy 2014				
Chaussy 2013				

Friedmacher 2015	

RCCS: retrospective case-control study; RCS: retrospective cohort study

Table 2. Summary of complication reported in the comparative studies regarding fundoplication

	Robotic fundoplication		**Laparoscopic fundoplication**	
	N	Details	N	Details
Ivascu, 2004	0/17	/	0/34	/
Lehert 2006	0/10	/	0/10	/
Copeland 2008	7/50	Tight wrap requiring dilatation (4)	8/50	Tight wrap requiring dilatation (3)
Al-Bassam 2009	2/25	Delayed gastric emptying (2)	2/25	Delayed gastric emptying (1) Dysphagia (1)
Anderberg 2009	2/14	Umbilical port site hernia (1), wound infection (1)	1/10	Wound infection (1)
Antao 2010	1/19	Recurrence (1)	2/33	Recurrence (2)

Table 3. Summary of complications reported in comparative studies regarding open and robotic pyeloplasty [13-22]

	Robotic Pyeloplasty			**Open Pyeloplasty**	
	N	Details	Mechanical Failure	N	Details
Yee 2006	1/8	Ileus (1)	1	1/8	UPJ stricture (1)
Lee 2006	1/33	Worsening hydronephrosis (1): redo		0/33	/
Sorensen 2011	5/33	Urinary leakage (4): 2 treated conservatively, 1 nephrostomy; 1 stent replacement Bleeding (1): conservative	3	3/33	Dehydration (1) Stent migration (1) Pyelonephritis (1) All treated conservatively
Behan 2011	X/37	Not available	Not available	X/7	Not available
Dangle 2013	1/10	Omental incarceration: open repair	/	0/10	/

Barbosa 2013	1/58	Worsening of hydronephrosis: redo	/	6/154	Urinoma (2) Redo (3) Peri-renalcollection (1)
Bansal 2014	3/9	Urinary leak: nephrostomy(1) Ileus: conservative UTI (1)	/	4/61	Catheter displacement (2) Ileus (1) Obstruction: nephrostomy (1)
Sukumar 2014	12% of 758	Not available	Not available	9,6% of 4977	Not available
Varda 2014	8,8% of 690	Minor (Clavien I-II)	/	6,8% of 10545	6,3% minor 0,5% major (Clavien III-IV)
Liu 2014	X/320	Not available	Not available	X/2907	Not available

Table 4. Summary of complications reported in comparative studies regarding laparoscopic and robotic pyeloplasty

	RoboticPyeloplasty			**LaparoscopicPyeloplasty**	
	N	Details	Mechanical failure	N	Details
Franco 2007	1/15	Urinaryleakage (1)	1	3/12	Leak Infection
Kim 2008	0/84	/	/	2/58	Leak Infection
Subotic 2012	6/19	Port site hernia (1) Stentdisplacement (1) Macrohematuria (1) UTI (2) Anastomotic leakage (1)	Electric power failure (1)	5/20	Stent displacement (2): nephrostomy in 1 Severe pelvic dilatation (1): temporary nephrostomy UTI (2)
Casella 2013	X/23	Not available		X/23	Not available
Riachy 2013	2/46	Urine leak (2): vesical catheter placement		2/18	Liver puncture: conservative Migrated stent (PN)

Ganpule 2015	2/19	Persistent hydronephrosis(1): nephrectomy	Instrument Malfunction (1): conversion to laparoscopy	1/25	Persistent hydronephrosis: nephrectomy (1)

Table 5. Summary of complications reported in comparative studies regarding laparoscopic single site and robotic nephrectomy

	Robotic nephrectomy		**Lap Single Site nephrectomy**	
	N	Details	N	Details
Bansal 2014	2/24	Urinary retention Leak	1/8	Umbilical abscess
Kim 2012	x/11	Not available	x/11	Not available

Table 6. Summary of complications reported in comparative studies regarding open and robotic ureteral reimplant

	Roboticureteralreimplantation		**Openureteralreimplantation**	
	N	Details	N	Details
Sorensen 2010	2/13 EV	Ureteral obstruction Urinoma	3/26 IV	Dehydration, Pyelonephritis Wound infection
Smith 2011	3/25	UTI	1/25	Urine leak
Marchini 2011	5/19 IV 4/20 EV	Urinary retention, bladder leak Urinary retention	12/22 IV 2/17 EV	Hematuria Hematuria
Schomburg 2014	2/20 EV	Urine leak (1) Ureteral stenosis (1)	5/20 EV	Clavien I-II (4) Clavien III (1)

References

1. Ivascu FA, Geiger JG, Dongrowski R, et al. Experience with robotic laparoscopic Nissen fundoplication in children at a single institution. Presented at the 13th Annual Congress of the International Pediatric Endosurgery Group, Maui, HI, May 5–8, 2004.

2. Antao B, Merrigan T, Nemechek C, et al. Comparison of robotic and laparoscopic Nissen fundoplication in children. Presented at the 19th Annual Congress of the International PediatricEndosurgery Group, Waikoloa, HI, June 8–12, 2010.

3. Lehnert M, Richter B, Beyer PA, et al. A prospective study comparing operative time in conventional laparoscopic and robotically assisted Thalsemifundoplication in children. J PediatrSurg 2006;41:1392–1396.

4. Anderberg M, Kockum CC, Arnbjornsson E. Paediatric robotic surgery in clinical practice: A cost analysis. Eur J PediatrSurg 2009;19:311–315.

5. Copeland DR, Boneti C, Kokoska ER, et al. Evaluation of initial experience and comparison of the da Vinci surgical system with established laparoscopic and open pediatricNissen fundoplication surgery. JSLS 2008;12:238–240.

6. Albassam AA, Mallick MS, Gado A, et al. Nissenfundo- plication, robotic-assisted versus laparoscopic procedure: A comparative study in children. Eur J PediatrSurg 2009;19: 316–319.

7. Cundy TP, Harling L, Marcus HJ, et al. Meta analysis of robot-assisted versus conventional laparoscopic fundoplication in children. J PediatrSurg 2014;49:646–652.

8. Hambraeus M, Arnbjo #rnsson E, Anderberg M. A literature review of the outcomes after robot-assisted laparoscopic and conventional laparoscopic Nissen fundoplication for gastro- esophageal reflux disease in children. Int J Med Robot 2013;9:428–432.

9. Chaussy Y, Becmeur F, Lardy H, Aubert D.J Robot-assisted surgery: current status evaluation of abdominal and urological pediatric surgery. Laparo Endosc Adv Surg Tech A. 2013 Jun; 23 (6): 530-8.

10. Friedmacher F, Till H. Robotic-Assisted Procedures in Pediatric Surgery: A Critical Appraisal of the Current Best Evidence in Comparison to Conventional Minimally Invasive Surgery. J Laparo Endosc Adv Surg Tech A. 2015 Nov;25(11):936-43

11. Kim NY, Chang EY, Hong YJ, Park S, Kim HY, Bai SJ, Han SJ Retrospective assessment of the validity of robotic surgery in comparison to open surgery for pediatric choledochal cyst.Yonsei Med J. 2015 May;56(3):737-43.

12. Vasilescu C, Stanciulea O, Tudor S Laparoscopic versus robotic subtotal splenectomy in hereditary spherocytosis. Potential advantages and limits of an expensive approach. Surg Endosc. 2012 Oct; 26 (10): 2802-9. Epub 2012 Apr 5.

13. Yee DS et al (2006) Initial comparison of robotic-assisted laparoscopic versus open pyeloplasty in children. Urology 67(3):599–602

14. Lee RS et al (2006) Pediatric robot assisted laparoscopic dis-membered pyeloplasty: comparison with a cohort of open surgery. J Urol 175 (2): 683–687; discussion 687

15. Sorensen MD et al (2011) Comparison of the learning curve and outcomes of robotic assisted pediatric pyeloplasty. J Urol 185(6 Suppl):2517–2522

16. Behan JW et al (2011) Human capital gains associated with robotic assisted laparoscopic pyeloplasty in children compared to open pyeloplasty. J Urol 186(4 Suppl):1663–1667

17. Dangle PP et al (2013) Outcomes of infants undergoing robot- assisted laparoscopic pyeloplasty compared to open repair. J Urol 190(6):2221–2226

18. Barbosa JA et al (2013) Comparative evaluation of the resolution of hydronephrosis in children who underwent open and robotic- assisted laparoscopic pyeloplasty. J PediatrUrol 9(2):199–205

19.Bansal D et al (2014) Infant robotic pyeloplasty: comparison with an open cohort. J PediatrUrol 10(2):380–385

20.Sukumar S et al (2014) Correction of ureteropelvic junction obstruction in children: national trends and comparative effectiveness in operative outcomes. J Endourol 28(5):592–598

21.Varda BK et al (2014) National trends of perioperative outcomes and costs for open, laparoscopic and robotic pediatric pyeloplasty. J Urol 191(4):1090–1095

22.Liu DB et al (2014) Contemporary national comparison of open, laparoscopic, and robotic-assisted laparoscopic pediatric pyeloplasty. J PediatrUrol 10(4):610–615

23.Song SH, Kim KS. Current status of robot-assisted laparoscopic surgery in pediatric urology. Korean J Urol. 2014 Aug;55(8):499-504.

24.Chang SJ, Hsu CK, Hsieh CH, Yang SS Comparing the efficacy and safety between robotic-assisted versus open pyeloplasty in children: a systemic review and meta-analysis. World J Urol. 2015 Nov;33(11):1855-65. 24.

25.Franco I, Dyer LL, Zelkovic P. Laparoscopic pyeloplasty in the pediatric patient: Hand sewn anastomosis versus robotic assisted anastomosis—Is there a difference? J Urol 2007;178: 1483–1486.
24.

26.Kim S, Canter D, Leone N, et al. A comparative study between laparoscopic and robotically assisted pyeloplasty in the pediatric population. J Urol 2008;179:357.

27.Subotic U, Rohard I, Weber DM, et al. A minimal invasive surgical approach for children of all ages with ureteropelvic junction obstruction. J PediatrUrol 2012;8:354–358.

28.Riachy E, Cost NG, Defoor WR, et al. Pediatric standard and robot-assisted laparoscopic pyeloplasty: A comparative single institution study. J Urol 2013;189:283–287.

29.Casella DP, Fox JA, Schneck FX, et al. Cost analysis of pediatric robot-assisted and laparoscopic pyeloplasty. J Urol 2013;189:1083–1086.

30.Ganpule A, Jairath A, Singh A, Mishra S, Sabnis R, Desai M Robotic versus conventional laparoscopic pyeloplasty in children less than 20 kg by weight: single-center experience. World J Urol. 2015 Nov;33(11):1867-73.

31.Braga LH1, Pace K, DeMaria J, et al. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: Effect on operative time, length of hospital stay, postoperative complications, and success rate. Eur Urol 2009;56:848–857.

32.Autorino R, Eden C, El-Ghoneimi A, et al. Robot-assisted and laparoscopic repair of ureteropelvic junction obstruction: A systematic review and meta-analysis. Eur Urol 2014;65:430–452.

33.Cundy TP, Harling L, Hughes-Hallett A, et al. Meta-analysis of robot-assisted vsconventionallaparoscopic and open pyeloplasty in children. BJU Int 2014;114:582–594.

34.Bansal D, Cost NG, Bean CM, et al. Comparison of pediatric robotic-assisted laparoscopic nephroureterectomy and laparoendoscopic single-site nephroureterectomy. Urology 2014;83:438–442.

35.Kim PH, Patil MB, Kim SS, et al. Early comparison of nephrectomy options in children (open, transperitoneal laparoscopic, laparo-endoscopic single site (LESS), and robotic surgery). BJU Int 2012;109:910–916.

36.Sorensen MD, Johnson MH, Delostrinos C, et al. Initiation of a pediatric robotic surgery program: Institutional challenges and realistic outcomes. Surg Endosc 2010;24:2803–2808.

37.Smith RP, Oliver JL, Peters CA. Pediatric robotic extravesical ureteral reimplantation: Comparison with open surgery. J Urol 2011;185:1876–1881.

38.Marchini GS, Hong YK, Minnillo BJ, et al. Robotic assisted laparoscopic ureteral reimplantation in children: Case matched comparative study with open surgical approach. J Urol 2011;185:1870–1875.

39.Schomburg JL, Haberman K, Willihnganz-Lawson KH, Shukla AR. Robot-assisted laparoscopic ureteral reimplantation: a single surgeon comparison to open surgery. J Pediatr Urol. 2014 Oct;10(5):875-9.

40.Lee NG, Corbett ST, Cobb K, Bailey GC, Burns AS, Peters CA. Bi-Institutional Comparison of Robot-Assisted Laparoscopic Versus Open Ureteroureterostomy in the Pediatric Population.JEndourol. 2015 Nov;29(11):1237-41.

41.Grimsby GM, Jacobs MA, Gargollo PC. Comparison of Complications of Robot-Assisted Laparoscopic and Open Appendicovesicostomy in Children. J Urol. 2015 Sep;194(3):772-6. doi: 10.1016/j.juro.2015.02.2942.

42.Alemzadeh H, Raman J, Leveson N, Kalbarczyk Z, Iyer RK Adverse Events in Robotic Surgery: A RetrospectiveStudy of 14 Years of FDA Data. PLoSOne. 2016 Apr 20;11(4):e0151470.