Robotic-Assisted Laparoscopic Surgery (RALS) in Pediatric Urology

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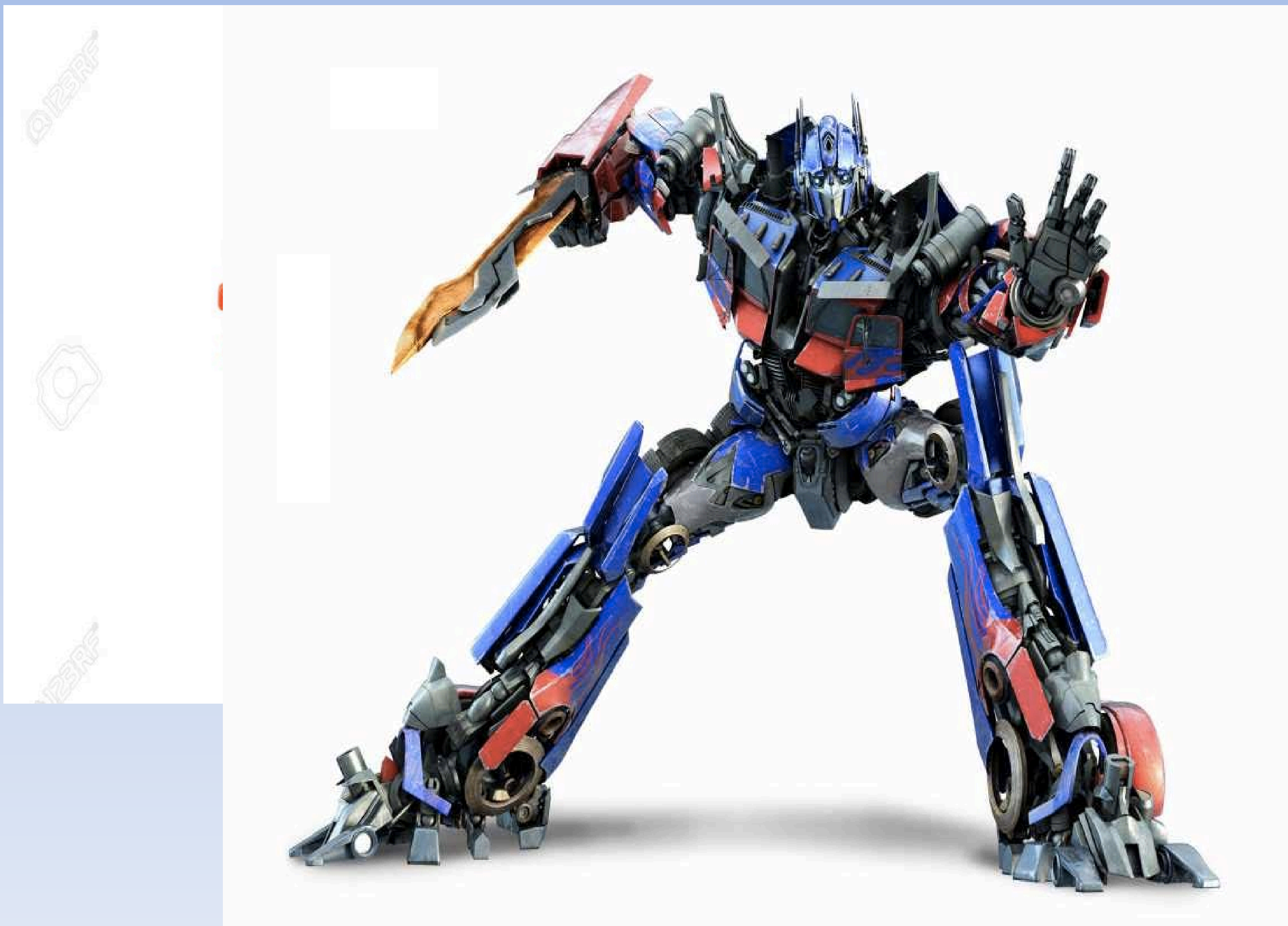
Robotics in Surgery



Robotic-Assisted Laparoscopic Surgery

- Advantages:
  - Quicker postoperative recovery
  - Fewer analgesic requirements
  - Shorter length of hospital stay
  - Conventional laparoscopic surgery
    - Technically demanding
    - Steep learning curve

Trevisani 2013, Tomaszewski 2012

Robotic-Assisted Laparoscopic Surgery

- Advantages:
  - Magnified three-dimensionality
  - Superior stereoscopic visualization
  - Enhanced dexterity
    - Wrist-like with 90 degrees of articulation
    - 7 degrees of freedom
  - Improved precision of movement
    - Tremor filtration
    - Ergonomic comfort

Camarillo 2004

Robotics in Pediatric Urology

- Is Robotic Surgery feasible in children?
  - Considerations in RALS in Pediatrics
- Is Robotic Surgery applicable to Urologic surgery in children?
- Is Robotic Surgery successful in surgery?
- Is Robotic Surgery advantageous over open surgery in children?

RALS: Pediatric Urology

- Laparoscopy is effective in pediatrics
- RALS in Pediatrics is similar to RALS in Adults… ……………………………………with some exceptions

Considerations in Pediatric RALS

- Pneumoperitoneum:
  - 5-6 L in adults….1 L in a 1 year old
  - Working Pressure:
    - Infants (0– 2 y)>>> 8 to 10 mm Hg
    - Children (2–10 y)>>> 10 to 12mm Hg
    - Adolescents (> 10 y) >>> 15mm Hg

- Small "working area"
  - Limits robotic mobility
    - Port site conflicts
    - Instrument collision
    - Potential increase risk of visceral injury

Casale 2010, Larobina 2005, Kutikov 2006

Considerations in Pediatric RALS

- Abdominal wall is thinner and more compliant
  - Increased risk of vascular injury
    - ~5 cm between abdominal wall and great vessels
    - Hasson open access technique for camera
    - All ports placed under direct vision
  - Increased risk of port expulsion
    - Rapid loss of insufflation and loss of vision
  - Difficulty maintaining insufflation during instrument exchange
    - Tie in trocars with heavy suture
  - Increased compliance
    - More“curved” abdomen
      - » Triangular of ports will maximize exposure.

Casale 2008,

Considerations in Pediatric RALS

- Bladder is an abdominal organ in small children
  - Foley to decompress the bladder
    - Prevents bladder injury

- ⬆ in inflation of stomach with anesthesia induction
  - NG for stomach decompression

Campbells Urology, 2016

Casale 2008,

Contraindications to Pediatric RALS

- **Cardiopulmonary morbidity**
- **Incorrected coagulopathy**
- **Sepsis**

Does Size Matter: Infant RALS

- Infants
  - No consensus on the appropriate infant candidate
  - No objective standards to guide decision making.

Does Size Matter: Infant RALS

- Casale et al.
  - 45 infants: 24 Female --- 21 Male
  - 3-12 months of age
  - Hypothesis: Smaller child = More robotic arm collisions
  - Methods:
    - » ASIS: distance between both anterior superior iliac spines
    - » PXD: puboxyphoid distance
    - – Compared ASIS and PXD distance
      - » Number of collisions/surgery
      - » Time on the Robotic Console

Does Size Matter: Infant RALS

- Results:
  - Strong correlation: ⬆ number of collisions ⬆ console time
  - Strong inverse relationship
    - ⬇ ASIS distance ⬆ number of collisions
    - ⬇ PXD distance ⬆ number of collisions
  - Independent of age, gender or weight
- Conclusion:

ASIS $\leq$ 13 cm or PXD $\leq$ 15 cm

- May impair surgeon and restrict surgery due to collisions

Finkelstein 2015

Does Size Matter: Obesity and RALS

- Cheng et al.
  - 103 children
    - 66 % healthy weight
    - 23% overweight
    - 10% obese
  - Results
    - Relative to healthy weigh children
      - » 7 min increase in OR time in overweight children
      - » 20 min increase in OR time in obese children
        - - ? Time for port Placement
      - » No differences in success rates
      - » No surgical site infections
  - Conclusion:
    - Obesity is not a limitation for RALS in children

Lindgren 2014

Pediatric RALS

- Conclusion:
  - There are special considerations in children
  - Smaller children may be challenging
    - Experience is important
  - Obesity is not a limiting factor

RALS Pediatric Pyeloplasty

Most common robotic procedure in pediatric urology

RALS Pediatric Pyeloplasty

Success Rates

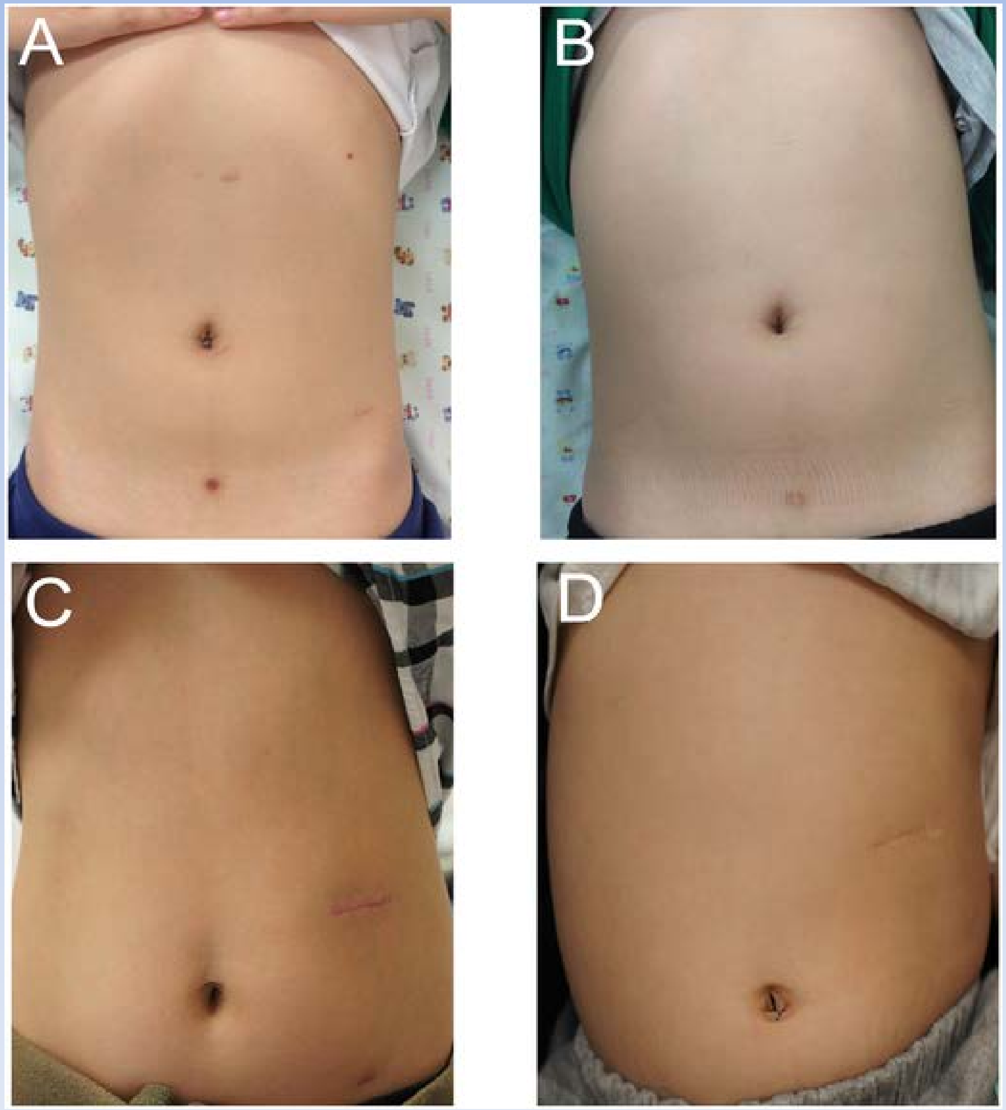
Table 2. Robot-assisted pyeloplasty series in the pediatric population.

Authors, year	No. of cases	Operation time (min)	Follow-up (months)	Complication rate	Success rate
Olsen, 2007 [32]	67	146	12	17.9	94
Sorensen, 2011 [29]	33	326	17	15.2	97
Minnillo, 2011 [31]	155	198	31	11	96
Singh, 2012 [68]	34	105	28	5.9	97
Avery, 2014 [24]*	62	232	12	11.3	91

*Outcomes reported by Avery *et al.* are that of an infant cohort.

Complication Rates

RALS Pediatric Pyeloplasty

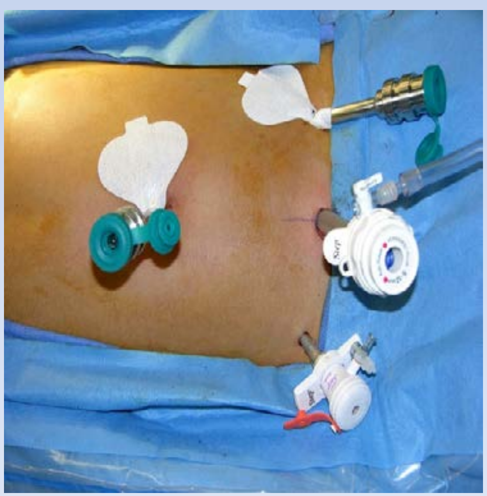


RALS

Lap-Asst

Song 2017

RALS Pediatric Pyeloplasty: HIdES

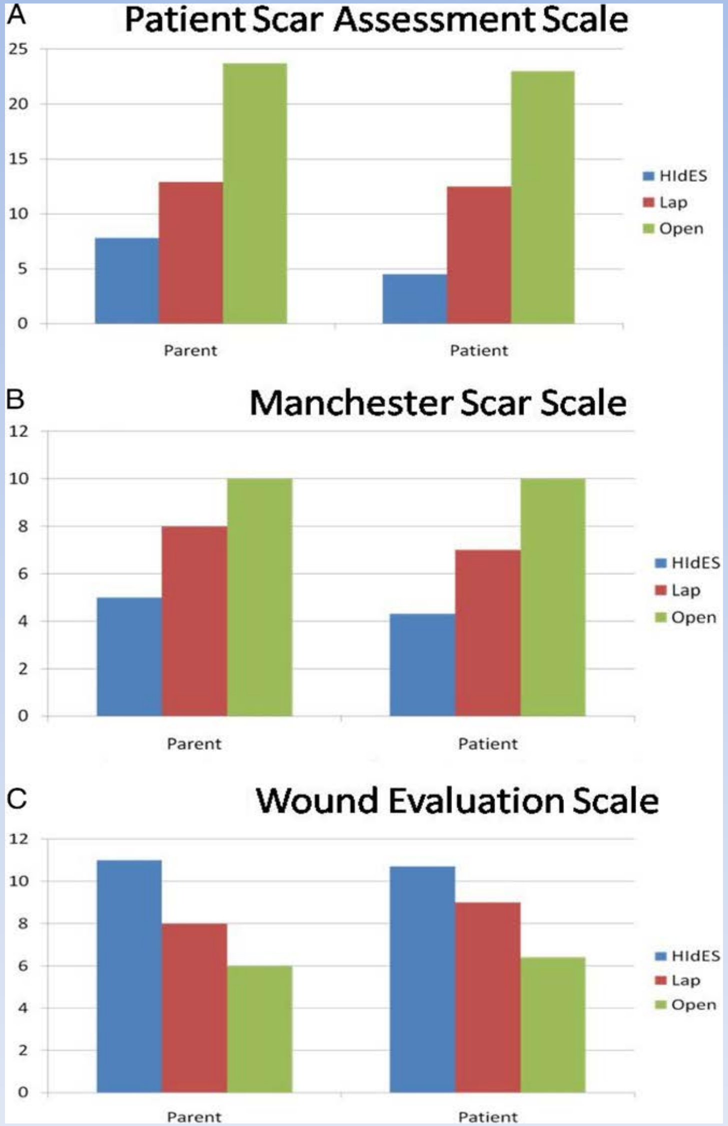


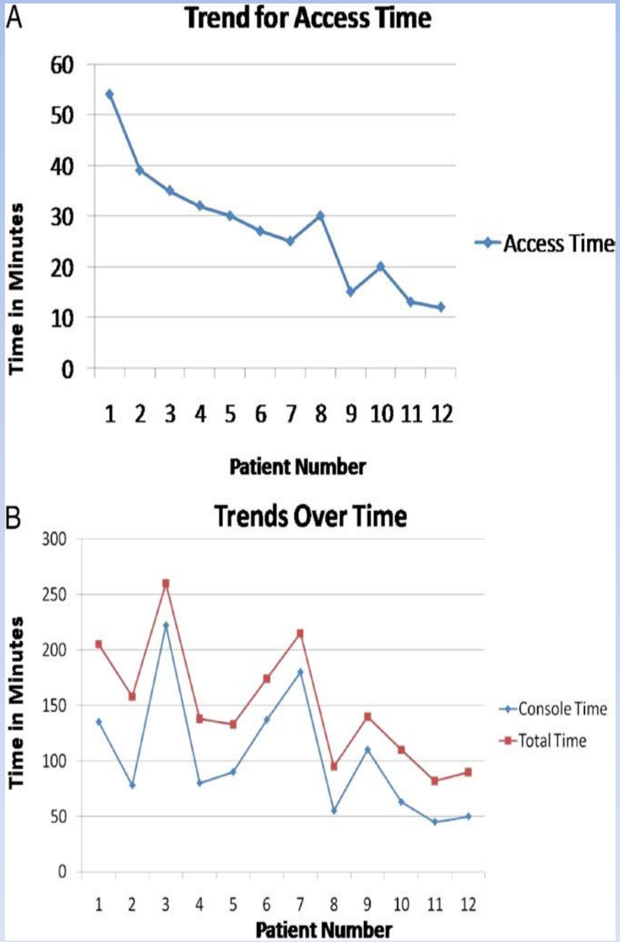
RALS-HIdES

Open Surgery

Gargollo, 2011

RALS Pediatric Pyeloplasty: HIdES





Gargollo, 2011

RALS Pediatric Pyeloplasty: Stentless

- Excellent success rates
- Low complication rate
- Avoids second procedure
  - Avoids anesthesia
- Post operative morbidity
  - No complaints of post operative stent pain
  - No bladder spasms
  - No Ileus
  - No fever or UTI

Silva 2015

RALS Pediatric Pyeloplasty: Reoperative Outcomes

Table 4 Clinical and imaging outcomes.

	All patients ($N = 23$)	>12 months follow-up ($N = 18$)
Median length of follow-up in months (range)	26 (4–45)	31 (16–45)
Resolution of pain in children with pain prior to reoperative RALP (%)	6/7 (86%)	5/6 (83%)
Hydronephrosis on follow-up ultrasound	$N = 22$[a]	$N = 17$[a]
Improved	18 (81%)	13 (76%)
Stable	3 (14%)	3 (18%)
Worse	1 (5%)	1 (6%)
Follow-up MAG-3	$N = 11$	$N = 9$
Improved/unobstructed	9 (82%)	7 (78%)
Stable/obstructed[b]	2 (18%)	2 (22%)
Additional intervention	4 (17%)	4 (22%)
Temporary stent	3	3
Balloon dilation of UPJ and multiple ureteral stents, ultimately underwent nephrectomy by outside surgeon	1	1

[a] Unable to obtain imaging in one patient (relocated out of state).
[b] Both patients without clinical evidence of obstruction but continued abnormal MAG-3. Further clinical details in text.

Davis 2016

RALS Ureteral Reimplant (RALUR): Pediatrics

- Indications for surgical treatment
  - Breakthrough UTI while on Antibiotic prophylaxis
  - Acquired Renal Scarring
  - Worsening or Severe Urinary Reflux
- Between 2000-2012
  - Total number of Reimplants decreased by 14%
  - Minimally Invasive Ureteral Reimplant
    - 0.3% in 2000 to 6.3% in 2012
      - 80% performed robotically

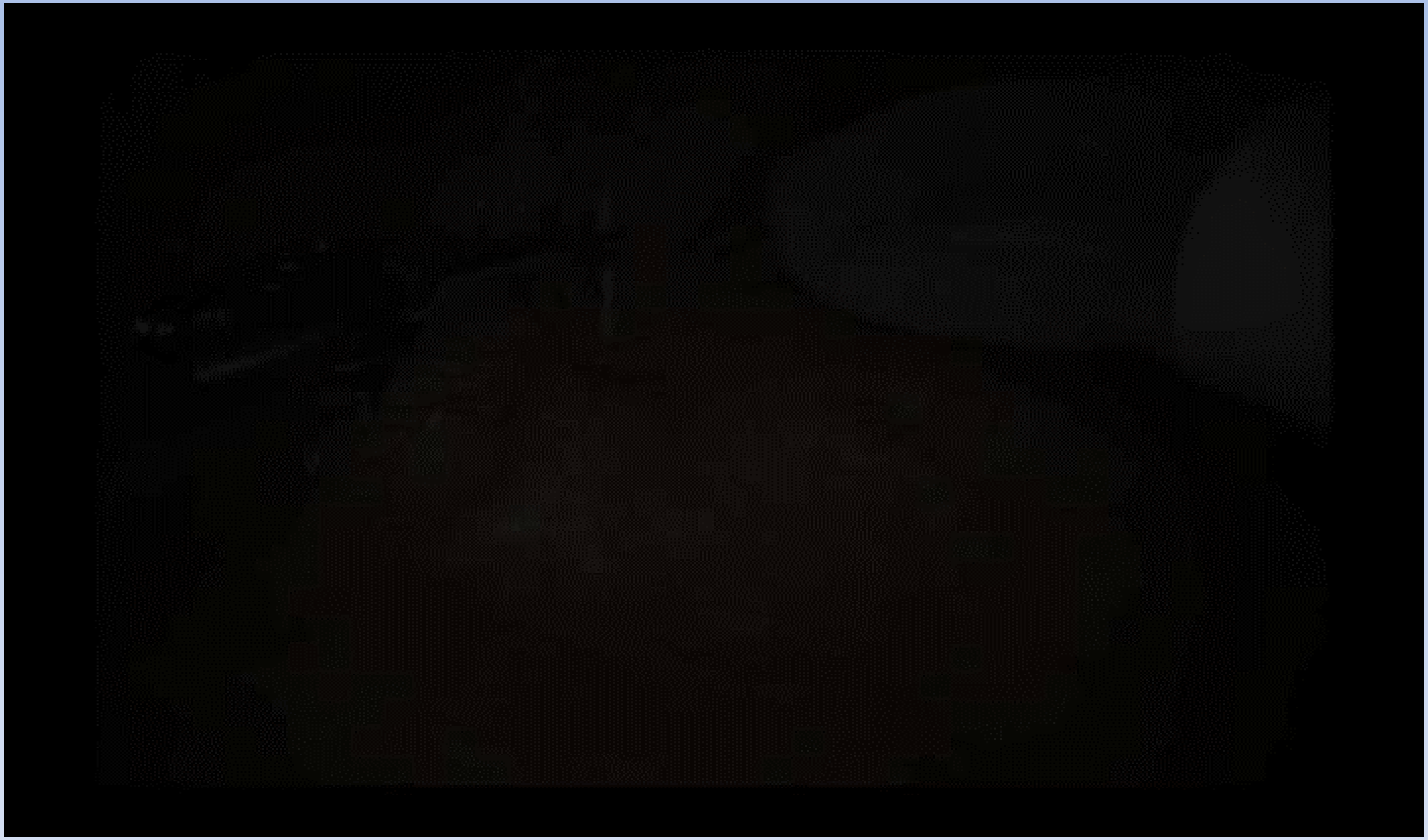
Bowen, 2016

RALS Ureteral Reimplant: Intravesical

- Intravesical Ureteral Reimplant
  - 2005 by Dr. Craig Peters
    - 6 patients 5-15 years
    - Cohen (Cross Trigonal)
  - Complications
    - 1 post-operative urine leak
  - Success Rate
    - 83% VUR resolution on post-operative VCUG.

Peters, 2005

RALS Ureteral Reimplant: Intravesical



Courtesy of Patricio Gargollo, MD Pediatric Urology Mayo Clinic

Marchini et al 2011:

- 92% success rate
- less bladder spams and less hematuria
- shorter hospital stay and shorter duration of urethral catheter drainage

RALS Ureteral Reimplant: Extravesical

- Extravesical Reimplant
  - 2004 by Dr. Craig Peters
    - Lich-Gregor procedure

    - Be aware of the neurovascular bundle (bilateral)
      - dorsomedial at the distal 2.5 cm of the ureter
      - dorsocranial to the trigone
        - » 10% transient urinary retention for open extravesicals

RALS Ureteral Reimplant: Extravesical

Study Number of patients Mean age years	Method of defining procedural success	Success rate	Reported complications	Follow up (weeks)
Casale, *et al.* 2008 [15] N=41 (41 bilateral) 3.2	Radiographic	98%	Febrile UTI [1]	31
Kasturi, *et al.* 2012 [16] N=150 (150 bilateral) 3.6	Radiographic	99%	Intra-abdominal urinary leak [1]	104
Akhavan *et al.* 2014 [17▪▪] N=50 (28 bilateral) 6.2	Radiographic	92%	Ureteral obstruction [2], ureteral injury [1], febrile UTI [5▪], ileus [2], perinephric fluid collection [1], urinary retention [1], contralateral de-novo VUR [5▪]	41
Dangle *et al.* 2014 [18] *N*=29 (11 bilateral) 5.3	Radiographic	80%	None reported	16
Grimsby *et al.* 2015 [19▪] *N*=61 (32 bilateral) 6.7	Radiographic and clinical	72%	Ureteral obstruction [3], urine leak [2], nonsurgical readmission [1]	51
Herz *et al.* 2016 [20] *N*=54 (18 bilateral) 5.2	Radiographic	92% unilateral 72% bilateral	Ureteral obstruction [4], urine leak [2], urinary retention [4], total reoperation [10], worsening postoperative BBD [12], postoperative UTI [6], nonsurgical readmission [2]	12
Arlen, 2016 [21] *N*=17 (3 bilateral) 9.3	Clinical	94%	Ureteral stricture with obstruction requiring reoperation [1], ileus [1], febrile UTI [1]	66

Timberlake 2017

RALS Ureteral Reimplant: Extravesical

Table 2 All 90-day complications experienced.

	Open ($n = 97$)[a]	Robotic ($n = 21$)[a]
Genitourinary	Urinary retention (5), postoperative hydronephrosis (5), obstruction of ureter or kidney (5), oliguria/anuria (2), acute kidney injury, hematuria (8), urinary extravasation, other urinary complications	Urinary retention (2), postoperative hydronephrosis (4), other ureteral abnormalities, oliguria/anuria, urinary frequency, complications of cystotomy, hematuria
Infection	Urinary tract infection (9), wound infection (4), other	Urinary tract infection (2)
Cardiovascular and respiratory	Tachycardia, dysrhythmias (2), pneumonia (4), asthma flare (3), bronchospasm, other	Tachycardia, pulmonary collapse, hypoxemia, asthma flare (2)
Hematologic	Anemia (2), hemorrhage complicating a procedure	
Gastrointestinal	Nausea/vomiting (14), paralytic ileus (5), constipation (7), abdominal pain (2), intestinal perforation	Constipation, abdominal pain

[a] Some patients in each group experienced multiple complications.

Conclusion: Statistically more complication in the RAL Ureteral Reimplants

Kurtz 2016

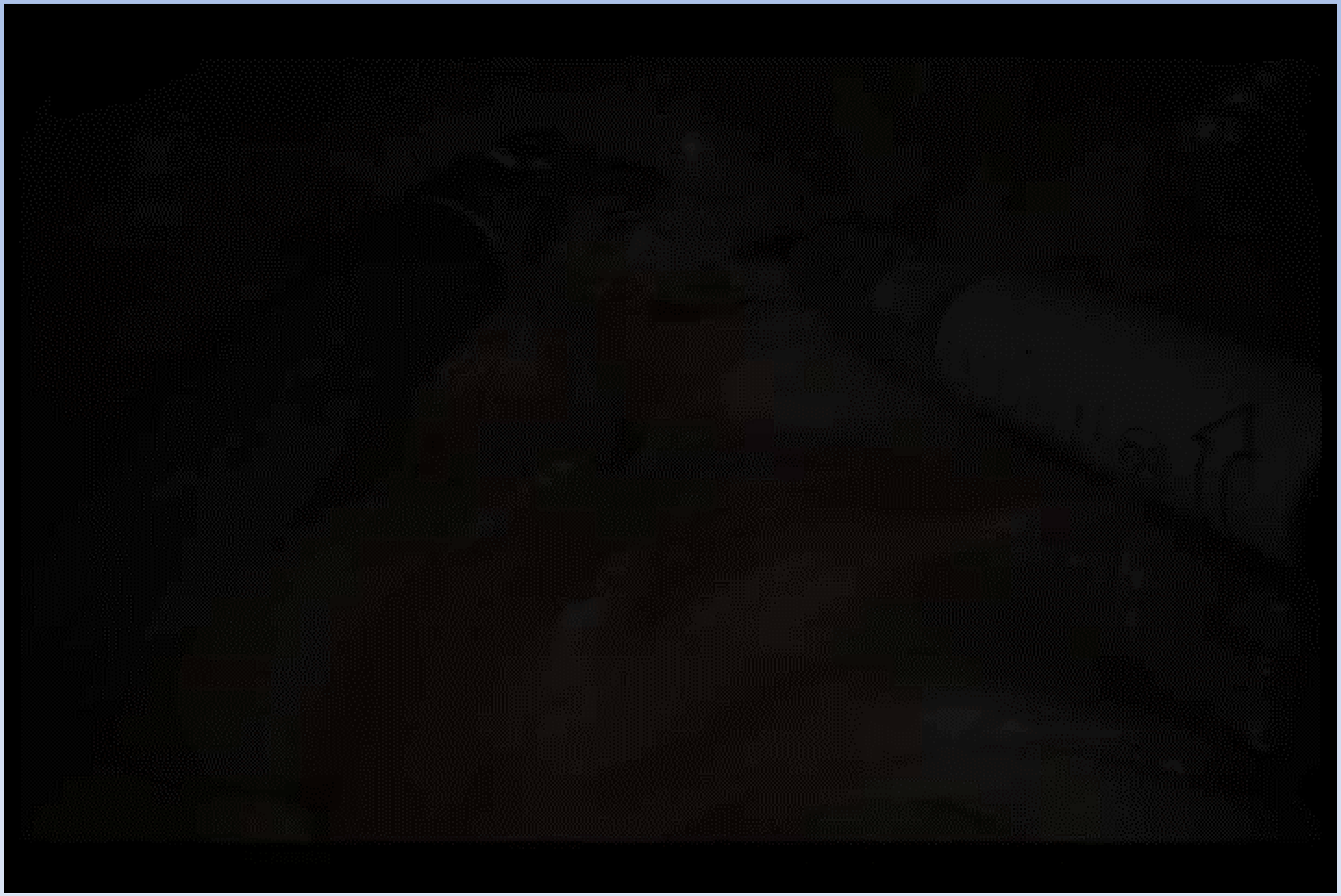
RALS Ureteral Reimplant: Complex Ureters

- Defined:
  - Megaureters >> Tapering and/or dismemberment
  - Duplicated collecting system
  - Ureteral Diverticulum
- Clinical Success
  - Absence of Febrile UTI at 16 mths follow-up
    - 94% RALS
    - 93% OUR

* OUR = open ureteral reimplant

Arlen, 2016

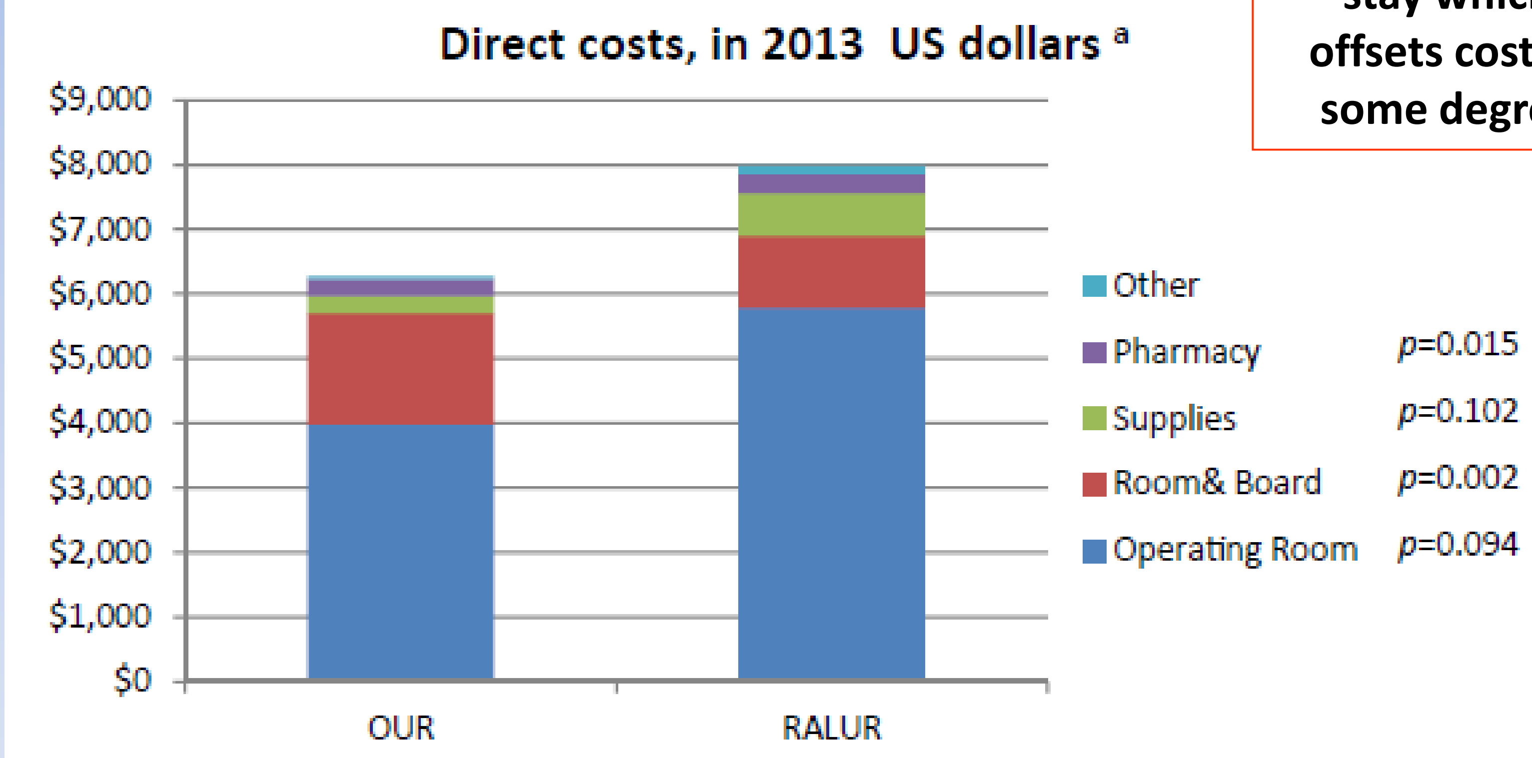
RALS Ureteral Reimplant: Complex Ureters



Courtesy of Patricio Gargollo, MD Pediatric Urology Mayo Clinic

RALS Ureteral Reimplant: Extravesical

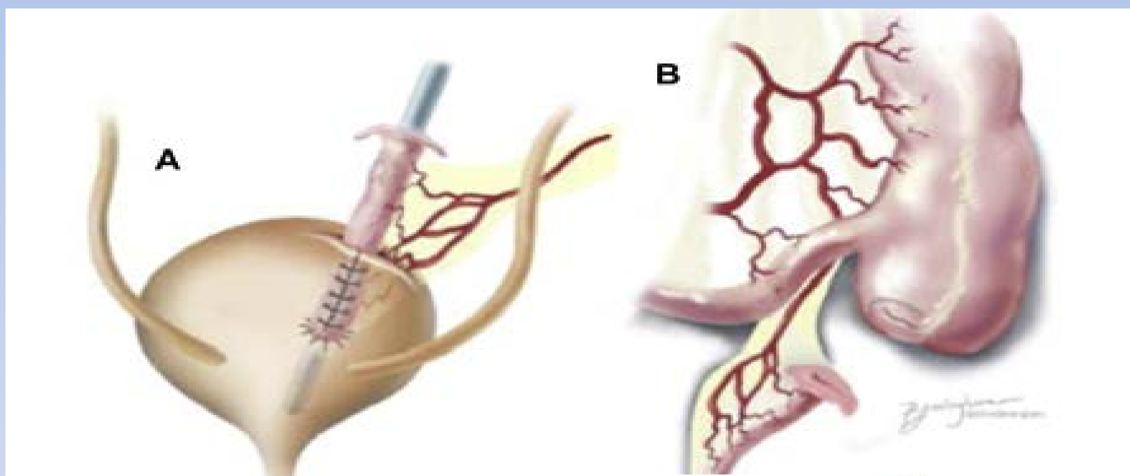
RALS is associated with shorter hospital stay which offsets cost to some degree

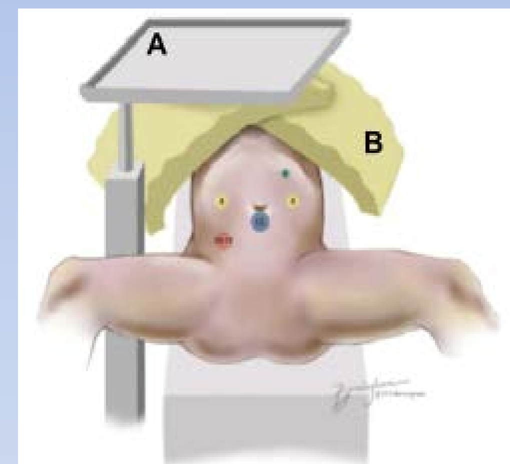


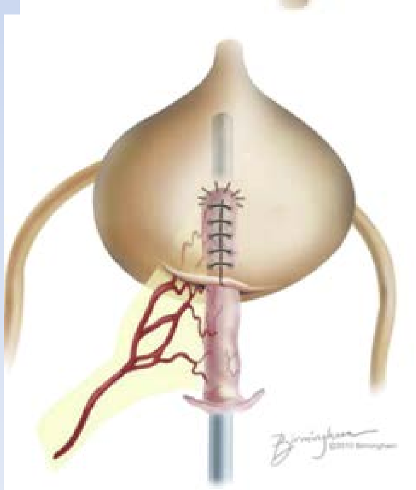
RALUR was associated with a significantly higher direct costs even when adjusted for demographic and regional factors

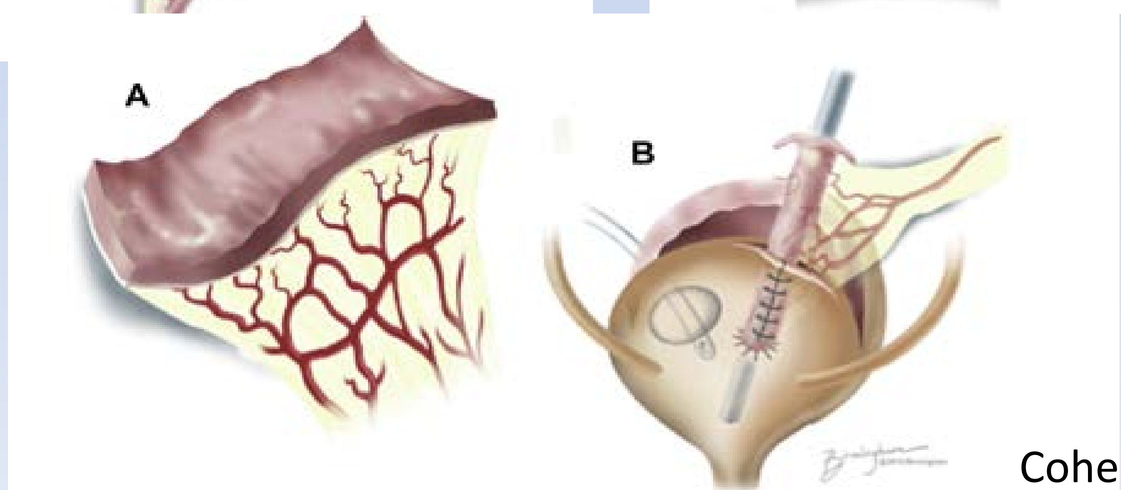
Kurtz 2016

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy



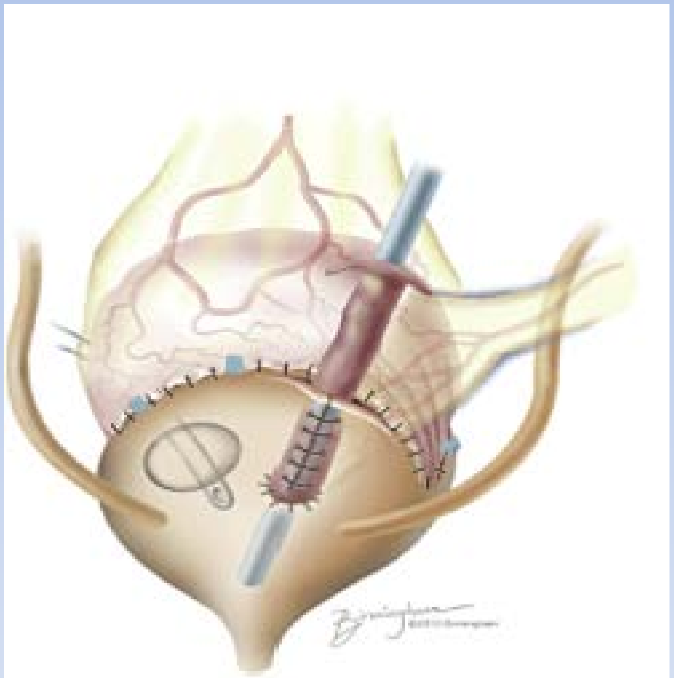






Cohen, 2015

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy



Cohen, 2015

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy

Table 1 – Patient characteristics

Characteristic	Robotic (n = 15)	Open (n = 13)	p value
Age, yr (IQR)	11.7 (8.1–13.8)	4.6 (3.5–6.6)	<0.01
Male, n (%)	9 (60)	6 (46)	0.71
Weight, kg (IQR)	37 (34–54)	23.5 (12.1–34.9)	<0.01
Body mass index, kg/m^2 (IQR)*	18 (16–27)	19 (16–22)	0.56
Wheelchair bound, n (%)	5 (33)	1 (8)	0.17
VP shunt, n (%)	7 (47)	4 (31)	0.46
Prior abdominal surgery, n (%)	2 (13)	8 (62)	0.02
Urinary incontinence, n (%)	13 (87)	10 (77)	0.64

IQR = interquartile range; OAI = open augmentation ileocystoplasty; RALI = robot-assisted laparoscopic augmentation ileocystoplasty; VP, ventriculoperitoneal. Indications for surgery included RALI: myelomeningocele (9 patients), sacral agenesis (3), tethered cord (2), posterior urethral valves (1); OAI: myelomeningocele (6), cloacal anomaly (4), posterior urethral valves (2), nonneurogenic neurogenic bladder (1).

* Height available in 11 of 15 robotic surgery patients.

Murthy, 2015

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy

Table 2 – Perioperative and hospital data

Characteristic	Robotic (*n* = 15)	Open (*n* = 13)	*p* value
Concomitant procedures			
Appendicovesicostomy, *n* (%)	11 (73)	10 (77)	1.0
Antegrade colonic enema, *n* (%)	6 (40); 3 with cecal flap	2 (15)	0.22
Bladder neck closure, *n* (%)	4 (27)	2 (15)	0.66
Operative time, min (IQR)	623 (532–659)	287 (269–339)	<0.01
Estimated blood loss, ml (IQR)	100 (50–100)	50 (60–200)	0.89
IV morphine equivalents, mg/kg (IQR)	0.49 (0.21–0.78)	0.70 (0.34–1.33)	0.33
Return to regular diet, d (IQR)	4 (2–5)	4 (4–6)	0.07
Length of stay, d (IQR)	6 (5–7)	8 (7–11)	0.01

CI = confidence interval; IQR = interquartile range; IV = intravenous.

Table 3 – Subprocedure operative times for robot-assisted laparoscopic augmentation ileocystoplasty with Mitrofanoff appendicovesicostomy

Procedure, patients reviewed	Time, min
Appendiceal harvest	28 (21–48; 7)
Ileal loop isolation and anastomosis	74 (68–107)
Cystotomy	30 (26–42)
Ileal detubularization	6 (4–10)
Appendicovesicostomy	82 (66–88)
Ileovesical anastomosis	121 (101–167)
Bladder neck closure	32 (22–54)

All procedure times are described as median (interquartile range).

Murthy, 2015

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy

Table 5 – Distribution of complications*

Complications	Robotic	Open	p value
Any, *n* (%)			
30-d	7 (47)	8 (62)	0.48
30–90 d	4 (27)	6 (46)	0.43
Highest grade, 30 d, *n* (%)			
None	8 (53)	5 (38)	0.26
Grade 1	5 (33)	4 (31)	
Grade 2	1 (7)	0	
Grade 3	1 (7)	4 (31)	
Highest grade, 30–90 d, *n* (%)			0.39
None	11 (73)	7 (54)	
Grade 1	1 (7)	3 (23)	
Grade 2	1 (7)	1 (8)	
Grade 3	2 (13)	2 (15)	

IQR = interquartile range.
Median follow-up: robotic, 43 mo (IQR: 19–69); open, 45 mo (IQR: 32–56); $p = 0.8$.
* Complications reported by the day after surgery when the complication was diagnosed.

Murthy, 2015

RALIMA: Robotic-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff appendicovesicostomy

Table 6 – Troubleshooting and tips for proficiency

Difficulty	Troubleshooting
High BMI	• Use bariatric ports after initial proficiency has been established
Kyphoscoliosis	• Move camera port supraumbilically if pubo-umbilical distance is short to reach small bowel
Appendix isolation in patients with a VP shunt	• Perform diagnostic peritoneoscopy • Anticipate adhesions and adhesiolysis • Appendix often found in subhepatic space
Short appendix requiring dual channels (MAPV or ACE)	• Utilize a cecal flap for creation of ACE channel
Presence of VP shunt	• Place lower end in Endopouch bag and keep in subhepatic space for duration of procedure
Short ileal mesenteric vessels	• Reducing Trendelenburg can help bring the loop into pelvis
Fatty mesentery	• First, resect bowel from antimesenteric side, and then take down mesentery for better identification of vessels • Consider Firefly if available
Mesenteric orientation and twisting	• Place stay sutures at proximal and distal ends of division segment, and maintain diligence for entire procedure • For appendix, place a stay suture on the mesenteric side of stomal end
Bladder neck closure	• Mobilize omentum and bring into pelvis with laparoscopy prior to robot docking to be used later to cover the repair to prevent dehiscence

ACE = antegrade colonic enema; BMI = body mass index; MAPV = Mitrofanoff appendicovesicostomy; VP = ventriculoperitoneal.

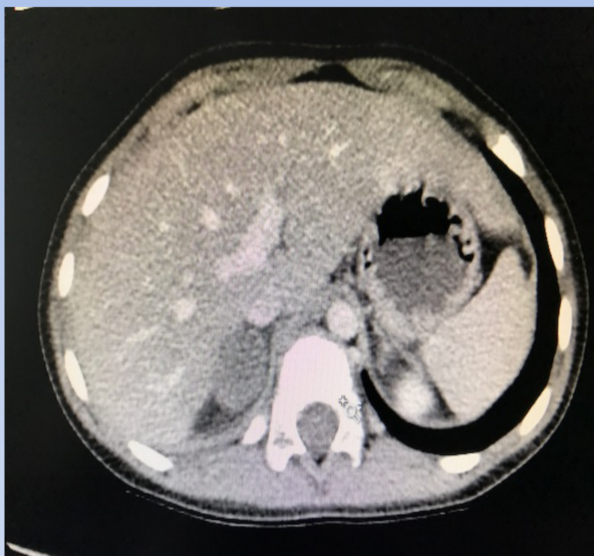
Required Conversion to open procedure

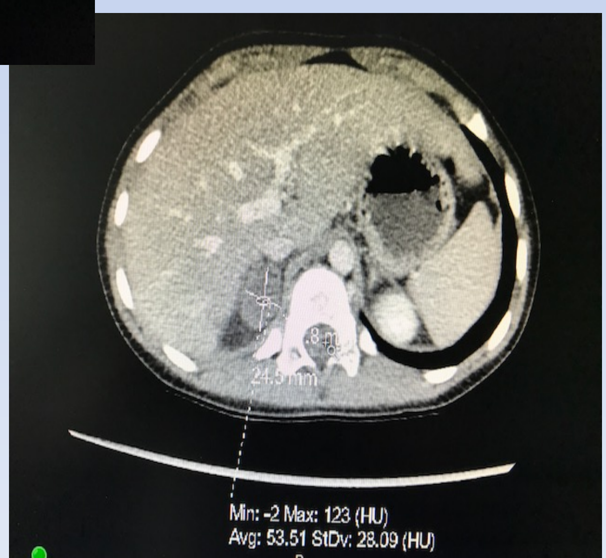
Murthy, 2015

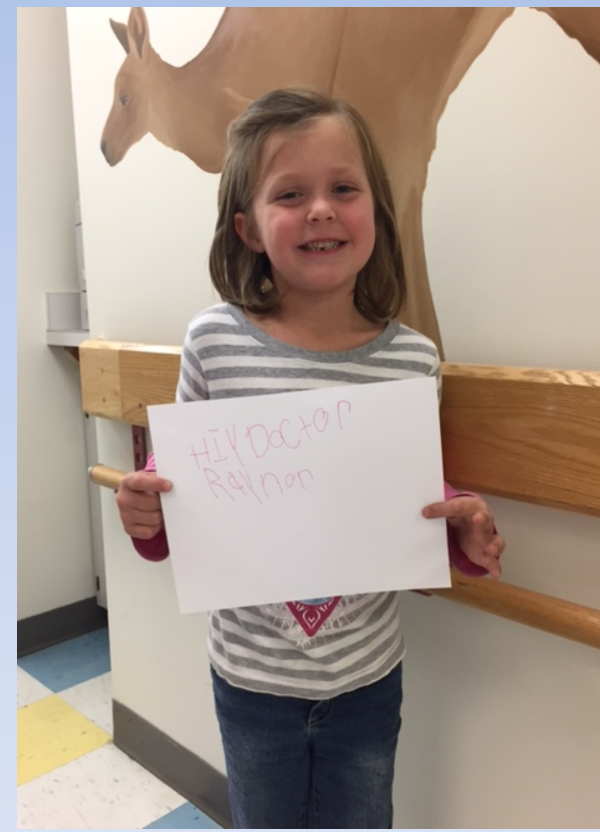
Robotic Assisted Surgery in Pediatric Urology at UNC

- RAL Pyeloplasty
- RAL Nephrectomy
  - Poorly functioning scarred kidney
  - Ectopic ureter with chronic urinary incontinence
- RAL Nephroureterectomy
- RAL Renal Cysto Decortication
  - Excision of Calyceal Diverticulum

Robotic Assisted Surgery in Pediatric Urology at UNC







Robotic Assisted Surgery in Pediatric Urology at UNC

15 yo male with ESRD with a history of a failed renal transplant who is on Peritoneal Dialysis

Scheduled for a RAL Retroperitoneal Nephrectomy in July

MAYO CLINIC

Pediatric Robotic Prostatectomy and Pelvic Lymphadenectomy for Embryonal Rhabdomyosarcoma

Deepak K. Agarwal, Tanner S. Miest, Candace F. Granberg, Igor Frank, Patricio C. Gargollo

Thank You!

The Worlds Most Human
Like Robot…..What’s Next?

References

1. Trevisani LFM, Nguyen HT. Current controversies in pediatric urologic robotic surgery. Curr Opin Urol. 2013;23:72–77.
2. Tomaszewski JJ, Casella DP, Turner RM 2nd, et al. Pediatric laparoscopic and robot-assisted laparoscopic surgery: technical considerations. J Endourol. 2012;26:602–613
3. Camarillo DB, Krummel TM, Salisbury JK. Robotic tech- nology in surgery: past, present, and future. Am J Surg. 2004;188:2S–15S
4. Larobina M, Nottle P. Complete evidence regarding major visceral injuries during laparoscopic access. Surg Laparosc Endosc Technol. 2005;5:119–123.
5. Casale P. Laparoscopic and robotic approach to genitourinary anomalies in children. Urol Clin North Am. 2010;37:279–286.
6. Kutikov A, Fossett LK, Ramchandani P, et al. Incidence of benign pathologic findings at partial nephrectomy for solitary renal mass presumed to be renal cell carcinoma on preoperative imaging. Urology 2006;68:737–740.
7. Casale P. Robotic pediatric urology. Expert Rev Med De- vices 2008;5:59–64.
8. Finkelstein JB, Levy AC, Silva MV, Murray L, Delaney C, Casale P. How to decide which infant can have robotic surgery? Just do the math. J Pediatr Urol. 2015 Aug;11(4):170.e1-4.
9. Lindgren B., Frainey B., Cheng E. et al. Robot assisted laparoscopic pyeloplasty in obese and non-obese patients. J Pediatr Urol. 2014 Dec. 10(6): 1206-11.
10. Song SH, Lee C, Jung J, Kim SJ, Park S, et al. (2017) A comparative study of pediatric open pyeloplasty, laparoscopy-assisted extracorporeal pyeloplasty, and robot-assisted laparoscopic pyeloplasty. PLOS ONE 12(4):
11. Gargollo PC. Hidden incision endoscopic surgery: description of technique, parental satisfaction and applications. J Urol. 2011 Apr; 185(4): 1425-31
12. Silva MV1, Levy AC2, Finkelstein JB2, Van Batavia JP2, Casale P2 Is peri-operative urethral catheter drainage enough? The case for stentless pediatric robotic pyeloplasty. J Pediatr Urol. 2015 Aug;11(4):175
13. Davis TD, Burns AS, Corbett ST, Peters CA. Reoperative robotic pyeloplasty in children. J Pediatr Urol. 2016 Dec;12(6):394

References

16. Bowen DK, Faasse MA, Liu DB, et al. Use of pediatric open, laparoscopic and robot-assisted laparoscopic ureteral reimplantation in the United States: 2000 to 2012. J Urol 2016; 196:207–212
17. Peters CA, Woo R. Intravesical robotically assisted bilateral ureteral reimplantation. J Endourol 2005; 19:618–621. discussion 21-22
18. Timberlake MD, Peters CA. Current status of robotic-assisted surgery for the treatment of vesicoureteral reflux in children. Curr Opin Urol. 2017 Jan;27(1): 20-26.
19. 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
20. Kurtz MP, Leow JJ, Varda BK, et al. Robotic versus open pediatric ureteral reimplantation: costs and complications from a nationwide sample. J Pediatr Urol 2016
21. Arlen AM, Broderick KM, Travers C, et al. Outcomes of complex robot-assisted extravesical ureteral reimplantation in the pediatric population. J Pediatr Urol 2016; 12:169e1–e6
22. Pedraza R., Weiser A, Franco I. Laparoscopic appendicovesicostomy (Mitrofanoff procedure) in a child using the da Vinci robotic system. J Urol. 2004; 171: 1652-1653.
23. Gundeti MD, Eng MK, Reynolds WS, et al. Pediatric robotic-assisted laparoscopic augmentation ileocystoplasty and Mitrofanoff appendicovesicostomy: complete intracorporeal-initial case report. Urology 2008; 72: 1144-7.
24. Cohen AJ, Pariser JJ, Anderson BB, Pearce SM, Gundeti MS. Urol Clin North Am. 2015 Feb; 42(1):121-30.
25. Murthy P, Cohn JA, Selig RB Gundeti MS. Robot-Assisted Laparoscopic Augmentation Ileocystoplasty and Mitrofanoff Appendicovesicostomy in Children: update Interm Results. Eur Urol. 2015 Dec; 68(6): 1069-75.