Chapter 1

Recent Advances in Pediatric Endourology

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Abstract

Minimally invasive endoscopic procedures in children with urological diseases have been proven to be safe, efficacious and with outcomes comparable and in some cases better than open surgical procedures. Recent advances in the pediatric endourology include improved instruments, benefits from better cosmetic results and decreased analgesic demands. In addition, length in hospital stay becomes more and more short. However, pediatric surgeons should not abandon the indications of open surgery. Furthermore, as the learning curve is not achieved easily, continuous education is needed.

Introduction

During the last few decades, a significant expansion of body of knowledge in the surgical management of pediatric urologic diseases has been observed. Pediatric surgeons have adopted the invasive approaches performed in the adult population, and applied them in pediatric population. Endourology, i.e. the endoscopic or percutaneous treatment of pediatric urological diseases has extended further as technology improvements in imaging tools and the introduction of smaller urological equipment have expanded the indications of these refinement techniques in the management of stone diseases, ureteroceles, vesicoureteral reflux, posterior urethral valves, and recurrent ureteropelvic junction obstruction.

In this article, we describe the latest developments in the current literature in endourology field in children. We
also discuss the current trends and outcomes in the application of these interventions.

A literature search in the PubMed database for studies related to advances in pediatric endourologic clinical applications was performed by using the following key words: pediatric endourology, kidney, ureter, bladder and urethra. Period of searching: 2010-till now. The following advances in pediatric endourology were retrieved.

Pediatric Nephrolithiasis

Nephrolithiasis is a major cause of morbidity across the world [1]. The exact incidence of kidney stones in the pediatric age group is unknown but it is estimated to have a prevalence of about 2% [2]. Infection and renal damage are the main potential causes of renal failure if nephrolithiasis remains untreated [3]. Bladder stones are found in less than 10% of children in North America, but it may be higher in other countries as a result of dietary factors [3]. Systemic risk factors such as diabetes, hypertension, decreased water intake, salt intake, and increased/decreased body weight [4,5]. Anatomic anomalies such as ureteropelvic junction obstruction (UPJO) or ureterovesical junction obstruction (UVJO) may be found during investigation for nephrolithiasis in 11-14% of children [6-8]. Other structural abnormalities may include bladder neck obstruction, horseshoe kidney, polycystic kidney disease, medullary sponge kidney and neuropathic bladder [9].

Although about 50% of stones in children may pass spontaneously [10], surgical intervention should be considered in cases of urinary obstruction, infection, solitary kidney, and prolonged symptomatic stones greater than 5mm [11].

Treatment options for pediatric nephrolithiasis include extracorporeal shock wave lithotripsy (ESWL), ureteroscopy (URS), percutaneous nephrolithotomoty (PCNL) and open stone removal via an open or a minimally invasive approach [12].

Extracorporeal Shock Wave Lithotripsy (ESWL)

ESWL was first introduced in pediatric population in 1986 by Newman et al [13]. Since then, the management of renal calculi in children has changed significantly [14], and ESWL is often the first line treatment of nephrolithiasis [15]. Major drawbacks of ESWL include the need for multiple sessions, especially with large calculi, the need for intervention for residual or obstructing calculi [16], possible deleterious effects of high energy shockwaves on the renal parenchyma, and potential harmful late systemic effects such as hypertension and diabetes mellitus [17,18]. Furthermore, animal studies have shown that ESWL may have histological changes in renal tubular, glomerular epithelium and interstitial cells and apoptotic effect on renal epithelium [17,19]. However, Lottmann et al [20] reported no parenchymal consequences on scintigraphy associated with ESWL even in previously damaged kidneys. Similarly results reported Fayad et al [21], who evaluated renal parenchyma using dimercapto-succinic acid and
glomerular filtration rate using diethylenetriamine penta-acetic acid before ESWL and six months later, reported no scars on scintigraphy or significant changes in glomerular filtration rate. They concluded that ESWL is a safe modality for treating renal calculi in children, with no long-term sequelae. Recently, in a systematic review and meta-analysis including 14 studies with 1842 patients, Lu et al [22] found that ESWL is efficient and with insignificant complications.

Current recommendations of European Association of Urology [23] suggest ESWL for the treatment of renal stones of a diameter up to 20mm (about 300mm²) in children. Studies have shown that the stone-free rate of ESWL ranges from 37-52% in the short-term period [24], and increases between 57% and 100% in the long term follow-up [25]. A significant factor that may affect the success rates is the localization of the calculi. Sampaio et al [26] reported that, due to gravity and anatomical position, stones localized in the lower calyces have lower success rates when treated with ESWL.

The following technical considerations are recommended (27): a) ESWL session should take half an hour and targets on the stone, b) the patient should be in a supine position, and should not move during the ESWL. General anesthesia is usually recommended in the case of a child less than 5 years, c) the power of the shock should be started from the lowest level (14kV) to reach a maximum level of 20kV until fragmentation is seen in fluoroscopy, d) the maximum number of shock wave should not exceed 1000 waves per session for children under 5 years of age, and a maximum of 2500 waves per session for older children. Retreatment with ESWL may be used in cases of residual stone larger than 4mm. No more than 3 sessions should be carried out. In the case of unsuccessful fragmentation, other procedures should be taking into account [27].

Complications arising from ESWL in children are usually self-limiting and transient. The most common complications include: renal colic, transient hydronephrosis, dermal ecchymosis, hematuria, urinary tract infection, ureteral obstruction, and sepsis [28].

**Percutaneous Nephrolithotomy (PCNL)**

**Procedure**

PCNL initially described in 1976 [29], rapidly became the most preferred method for management of large stone in adults [30]. The first PCNL in children was performed in 1997 by Mor et al [31] by using adult-sized instruments through a tract dilated as much as 30 Fr.

Indications for PCNL treatment include large upper urinary tract burden (>20mm in size, approximately 300mm²), lower pole stones greater than 1cm, presence of associated anatomic abnormalities (UPJO), a duplicated system, urinary diversion, patients with cystine or struvite
stones, and patients with hard and staghorn renal calculi [12,31].

Initially, there was a skepticism regarding the use of large instruments in pediatric population due to possible parenchyma damage, radiation exposure with fluoroscopy, and risk of complications such as sepsis and bleeding [12]. However, PCNL is frequently used either as monotherapy or combined with ESWL (sandwich therapy) with stone-free rates ranging from 80-93% after single treatment [32,33]. Furthermore, Guven et al [34] reported on 130 patients aged 3-17 years who underwent 140 PCNL sessions. Patients who had simple stones had a 100% stone-free rates and 84.6% were needed one access. However, children with more complex stones had 61% stone-free rates and required more than one access.

Technique in Children

The percutaneous procedure is performed under general anesthesia and in prone position [12]. A preoperative CT-scan is often obtained to determine the anatomy of the renal pelvis and calyceal system. Long et al [12] prefer to perform a single puncture technique, occasionally enhanced with preoperative ureteral catheter insertion for contrast instillation into the renal pelvis or insertion of a flexible ureteroscope for direct vision. Then they dilate the tract through a balloon instead of Amplatz dilators. The authors use either a rigid nephroscope 18-24 Fr, or a flexible nephroscope 15Fr via the same access sheath. Lithotripsy then is performed by using either a pneumatic or ultrasonic devices or the holmium:yttrium-aluminum-garnet (Ho:YAG) laser. Postoperatively, the options of collecting system include: no tube, a nephrostomy tube, an internal double J stent, and a percutaneous nephroureteral catheter. Concerns may arise regarding the proper size of percutaneous instruments. Although smaller instruments with size ranging from 11-18 Fr are currently available, there is not enough evidence whether they might generate lower morbidity or decrease general complication rates [35,36]. Nouralizadeh et al [37] reported on 20 patients younger than 5 years old underwent PCNL by using dilators up to 26 Fr and a 24-rigid nephroscope to fragment stones with a pneumatic lithotripter. The mean stone size was 33mm (range 20-46mm). Stones were effectively cleared in 79.16% of patients with an overall complication rate of 15.38%. They suggested that PCNL is effective and safe for renal calculi in children less than 5 years of age by using instruments designed for adults. On the contrary, Unsal et al [36] correlated the morbidity and success rates among two different aged groups of children (less than 7 years of age and more than 7 years of age) undergoing PCNL using either adult-or pediatric-sized instruments. They found that stone-free rates were similar, but children less than 7 years of age who had PCNL with adult-sized instruments had more needs of blood transfusions and bleeding complications than those children with smaller instruments.

Complications

Post-PCNL complications include bleeding requiring transfusion, sepsis, urine loss via the nephrostomy tract, pneumo-hydro-or hematotherax [38].
Mini-Perc, Micro-Perc, Ultraminiperc

Mini-Perc

Mini-perc was introduced in 1997 by Jackman et al [39]. It can be defined as PCNL with tract size equal or less than 20mm. There are two commercial systems: the Storz Miniperc available in three sizes 15/18, 16.5/19.5, and 21/24 Fr sheaths (Storz Miniperc) respectively, and the Wolf Miniperc, available in two sizes, with outer circumference of 15 and 18 Fr. Both have their own dilators, telescopes with 6.7 and 6 Fr working channels respectively. Stones of small size (1.5-2cm) can be removed either with forceps or basket [33]. Mini-perc shares comparable clearance rate as the standard PCLN, but is associated with less hemoglobin drop, hospital stay, analgesic requirements, and complication rates [40,41].

Micro-Perc

The perception was an imaginary question to the answer of how small can we go [42]. The armamentarium of Micro-perc consists of a 4.5 Fr needle, which has three parts: an outer sheath for passage of optics and energy source, a central part which comprises of a hollow needle and an innermost which comprises of a radiopaque stylet. Micro-perc is used for renal calculi less than 10mm, renal calculi in the lower calyx less than 10mm, not susceptible to flexible ureteroscopy because of difficult anatomy. In addition, Micro-perc could be used in pediatric urolithiasis and anomalous kidney such as ectopic kidneys [33]. Successful stone free-rate is reported in the range of 85-93% [93]. In the same study, the Micro-perc technique in children (aged 11 months to 15 years), had a stone-free rates of 93.3% at one month. Furthermore, in a recent study in children (aged 18 months to 11 years) who underwent Micro-perc lithotripsy, Calone et al [43] reported an overall stone-free rate of 100% at one month and without ancillary procedures.

Ultraminiperc

This instrument consists of a further narrow tract [44]. The basic component is a 6-Fr Mininephroscope which can be passed through an 11-to 13-Fr metal sheath. Stones are fragmented with 200-to 300-μm laser at 10-20W [33]. Direct vision is preserved with an irrigation pump. Ultraminiper-cc is indicated for stone less than 1.5cm.

The STPEDISET

Although the diameters of instruments in pediatric endourology have become smaller [45], the length of instruments for PCNL has not been sufficient for small children. Recently, Utaŋaç et al [46] designed a percutaneous set named Short and Thin Pediatric Set (STPEDISET). This set is composed of instruments comparable with those used for classical PCNL interventions [47]: a nephroscope, an Amplatz dilator set and auxiliaries, encompassing a Chiba needle and stone forceps.

ST nephroscope: a 9.5 Fr, 13cm-long pediatric compact cystoscope with a 60° angle of view (Karl-Storz, Japan)
is used as a nephroscope. This instrument can be manipulated within a 12 Fr access sheath. The shaft and intrarenal access instruments are parallel to each other in the working channel. Both rigid and flexible lithotriptors can be used.

**ST Amplatz dilator set**: consists of an 18 Fr introducer, three fascial dilators with a caliber of 6, 8 and 10 Fr, and five renal dilators with a caliber of 12, 14,16, and 20 Fr (Plastimed®, Turkey). The set contains five 9-cm long Amplatz sheaths, made of polyurethane.

**Auxiliaries ST (Chiba needle and stone forceps)**: the Ciba needle is 18G-thick and 13 cm - long, through which a 0.38-inch thick guide-wire can be passed. Stone forceps have a diameter of 5 Fr with a length of 28 cm and two prongs.

All interventions were performed under general anesthesia. PCNL (mini or ultramin PCNL) was performed in the prone position. The study included 21 children with a median age of 13 months (range, 5 months to 4 years) Stones were located in the renal pelvis and/or lower pole calyces; in some cases, they were multicalyceal. None of the patients required a second look or other intervention. The median operation time was 58 min (range, 40-95 min). The success rate was 85.7%. The overall complication rate was 9.5%, with a median stay of 4 days (range, 2-9 days). Although the results are promising, the authors suggested the need for further randomized studies to confirm these results.

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**Ureteroscopy (URS)**

Ureteroscopy was first introduced by Ritchey et al [48] in a young child with distal calyceal stones. Initial arguments included possible traumatic consequences to the pediatric ureter when using large-caliber ureteroscopes designed for adults [38]. However, technological improvements in the pediatric URS with the use of smaller flexible and semirigid endoscopes, and the introduction of the Ho:YAG laser, showed that URS may be superior to ESWL, with a stone-free rate ranging from 89-100% [49-52]. Although ESWL is the first line treatment for most ureteral stones, with the use of small-caliber instruments, the treatment of choice for medium and larger than 10mm distal ureteric stones in children is URS [23].

Currently, an expanded array of semirigid and flexible ureterscopes are applicable for use based on stone location, anatomy, and predilection of the surgeon. Available semirigid ureterscopes have a size ranging from 4.5 Fr to 8 Fr with working channels of 2.4 to 3.5 Fr [2]. Flexible ureterscopes may be used with size of 6.9 Fr and working channels of 1.8 to 3.5 Fr. Lithotripsy may take place either with direct fragmentation and extraction using a pneumatic lithotripter, Ho:YAG laser, or ultrasonic lithotriptors [2,35,51].
Technique in Children

Before Surgery

Stone localization is investigated with x-ray of the bladder, kidneys and ureters and by U/S. A DMSA is indicated in the case of a poor renal function [38]. Any urinary tract infection should be treated before URS.

Operation

Under general anesthesia and in dorsal lithotomy position, a hydrophilic wire is inserted in the ureteral orifice via a cystoscope of 7.5 or 11 Fr. The wire is advanced to the renal pelvis bypassing the stones. For stones distal to the iliac vessels, a 4.2 semirigid ureterscope may be used, and for more proximal ureteral stones a flexible 6.5 Fr ureterscope is used [38]. In the latter case an Amplatz dilator of the ureter orifice may be used. Fragmentation of the stones is usually performed with Ho: YAG laser [38]. At the end of the procedure, a stent may be left for 4 weeks to avoid a possible stricture of the ureteral orifice. Fragments are extracted with basket. In older children, larger caliber ureterscopes may be used. In these cases, an ureteral stent could be left for 1 week. Potential complications include ureteral ischemia, ureteral stricture and vesicoureteral reflux [53].

Bladder Stones

A number of different conditions such as posterior urethral valves, urethral strictures, foreign bodies, vesicoureteral reflux and voiding disturbances may influence the creation of bladder stones [54]. Although in developed countries a decrease of bladder stones has been noticed, in developing countries an increase of occurrence has been reported [55].

Open cystolithotomy, ESWL, percutaneous suprapubic cystolithotripsy and transurethral cystolithotripsy are the options available for treatment of bladder stones [56]. Open cystolithotomy has been associated with scar development, prolong hospitalization, and risk of infection [57]. ESWL, although less invasive method, may be accompanied with pain during passage of stones through the urethra, and the need of multiple sessions to achieve a desirable success rate [54]. Percutaneous suprapubic cystolithotripsy has been used with successful results in children and infants with bladder stone size ranging from median size of 2.3cm and 1.4cm respectively [58,59]. However, they have a lot of disadvantages such as the presence of incision, the dilation of the tract, the insertion of a suprapubic catheter, the use of urethral catheter, and the possible injury of bowel, specifically in the case of previous abdominal surgery [60,61].

Recently, Aboulela et al [54], reported a study of 33 children (median age, 3 years-range, 0.5-11years), with vesical stones (1-4cm). They performed a transurethral cystolithotripsy with the use of Ho: YAG laser applied at power of 30W using a semirigid cystoscope of 7.5 Fr or 9-11 Fr for younger and older children respectively. They reported a success rate of 100% in all children and without any complications. All children were free of stones at
mean follow-up of 11 months. All, but four patients, were discharged within 24 hours, and without bladder drainage. The authors stated that Ho: YAG laser is a safe and promising alternative for bladder stones. However, some limitations of the study, such as the exclusion of patients with stones more than 4mm, and the lack of a control group, pose the need for further investigation.

Ureteroceles

A ureterocele is a congenital cystic dilatation of the submucosal portion of the intravesical ureter. It is furthermore classified as intravesical ureterocele when it lies entirely within the bladder and ectopic ureterocele when it protrudes below the bladder neck. An ureterocele may be single when it is coexisted with a single ureter or may affect the upper portion of the kidney with complete pyeloureteral duplication [62,63]. Coexistent pathophysiologic sequelae include intravesical ureteral obstruction of the ureterocele-associated portion (40-70%) and vesicoureteral reflux (VUR) to the ipsilateral inferior portion (50%) or the contralateral kidney (25%) (64). Less often pathophysiologic features include: bladder neck obstruction, and mechanical obstruction of the inferior portion of the ipsilateral ureter or the contralateral ureter. It is noteworthy, that the presence of ureterocele and associated pyeloureteral duplication, may be asymptomatic without any pathological findings. Recent studies indicate a conservative management of small, non-obstructive intracystical ureteroceles, even in the presence of low grade reflux [65,66].

Optional treatments include conservative treatment, endoscopic treatment, upper pole nephrectomy, high or low ureteroureterostomy, and reimplantation of the affected ureter after excision of the ureterocele [65].

Endoscopic Management of Single Intravesical Ureterocele

Endoscopic puncture is the indicating method of treatment, offering a definite therapy in 70-80% of the cases [67]. Furthermore, surgery should be avoided near the bladder trigone. Indications include patients with ureterocele and systemic infection, azotemia, and severe obstruction [68]. Operative details include the use of an 8-Fr or 10-Fr endoscope and a 3-Fr flexible monopolar wire (in older children, a Collin knife may be used), and cutting distally to the ureterocele, allowing breakdown tissue to set up an antireflux mechanism [69].

Endoscopic Management of Ectopic Ureterocele and Ureteroceles Associated with Double Pyeloereteral System

Ectopic ureteroceles are accompanied by an unsuccessful operating rates after the initial endoscopic puncture [67]. Husmann et al [70] found that endoscopic decompression in children with ectopic ureterocele had a 64% failing rate. Additional studies support their findings [71,72].

In conclusion, it appears that endoscopic transurethral puncture represent a limited procedure without a
precise therapy in a large number of studies [70,73]. In view of these results, an evidence-based management does not exist, and therefore an upper tract approach should be considered [67]. Minimally invasive surgery, either laparoscopic or robotic, indicates a safe and efficient alternative to open surgery [67].

Vesicoureteral Reflux

Vesicoureteral reflux (VUR) refers to the reverse flow of urine from the bladder into the ureter or up to the pelvis and renal calyces. The exact incidence is difficult to estimate, as it is often asymptomatic. However, it is expected to affect 1-9% of all children [74]. A familial occurrence also has been observed, as one third of siblings of a child with VUR may have VUR [75]. The lesion may be primary or secondary to functional abnormalities (neurogenic bladder, voiding dysfunction) or anatomical abnormalities (posterior urethral valves).

Management objectives include prevention of the urinary tract infection, and renal damage. Consequently, management encompasses simple observation with or without antibiotic prophylaxis, and surgical interventions such as endoscopic agents injection, open, laparoscopic or robotic-assisted laparoscopic ureter reimplantation, depending on the underling situation and the preference of the surgeon.

Endoscopic Management of VUR

The endoscopic management of VUR was first proposed by Matousechek in 1981 [76], who used polytetrafluoroethylene (Teflon), and then was further expanded worldwide by O’Donnell et al [77] who introduced the subureteric Teflon injection (STING) procedure. This method involves the injection of Teflon 2 to 3 mm distal to the ureterovesical junction and 4 to 5 mm advancement of the needle in the submucosal plane, and the creation of a rise that lengthens the intramural ureter. The technique was further modified by Kirsch et al [78] who reported success rates superior to the STING procedure. Recently, Karabacacak et al [79] compared the two techniques and found that the modified STING technique provides statistically better results for grade IV VUR than the STING.

In the endoscopic treatment of VUR, various biological materials have been used such as collagen, chondrocytes, polydimethylsiloxane (PDS), and dextranomer/hyaluronic acid copolymer (Dx/Ha) [80]. Among them, PDS and Dx/Ha are the most popular used materials [80]. Recently, in the complicated cases of VUR with other congenital anomalies of the urinary tract, Kajbafzadeh et al [81] investigated the outcome of 2810 children with VUR. Among them there were 143 (5%) with concomitant VUR and UPJO. Twenty-six (18.2%) underwent endoscopic Dx/Ha injection. At 20±1.6 months, 76.9% of them showed resolution of VUR and spontaneous relief of UPJO. The authors state that ingenious techniques may reduce the need for pyeloplasty in selected cases.
Although endoscopic treatment of VUR has lower success rates compared to surgical ureters reimplantation (59.2% to 79.9% and 97% to 99% respectively) [82-86] the advantages of endoscopic treatment such as no scars, easy to perform, and less pain, could not be ignored. Factors that may be involved in the decrease of success rates include previous surgical ureteral reimplantations or co-existent functional or anatomic abnormalities [87]. Additionally, arguments may arise regarding the long-term effect of endoscopic treatment of VUR. Sedberry-Ross et all [88] reported a recurrence of 92% among high-risk patients with VUR. In line were the findings of Chi et al [89] who reported that 50% of patients who underwent Dx/Ha procedure had recurrent VUR.

We could conclude that there are not new techniques or agents in the field of endoscopic treatment of VUR, especially in patients with high-grade of the lesion. Further studies, and probably more sophisticated techniques are needed for improvement of minimally endoscopic procedures.

Posterior Urethral Valves

Posterior urethral valves (PUV) refers to a rare congenital obstruction of the posterior urethra in males, affecting 1/4000-75000 infants [90]. The most common demonstration is performed during an ordinary prenatal U/S, with precise diagnosis after birth [90]. Twenty-five to 50% of PUV cases are diagnosed in the neonatal period, and 50-70% in the first year of life. Clinical features after birth include poor urinary stream, urinary tract infection, and failure to thrive. In older children, diurnal diuresis, severe voiding complaints (dribbling, retention and hematuria), and infections have been reported [91,92].

The aim of PUV management is to relieve the obstruction and elevated pressure in the urinary tract, in order to preserve normal bladder and renal function. The most common method begins with catheter drainage initially, and endoscopic valve ablation, when the neonate is stable.

Recently, Martinez et al [93] reported, that fetal cystoscopic ablation of PUV is possible in most cases. Normalization of voiding was seen in 16/20 (80%) of the patients. No significant complications were reported. The method in brief includes a cutaneous incision under local anesthesia. After careful localization of the fetus with U/S, a fetoscope is inserted into the bladder. The fetoscope consists of a 2.3x1.2mm sheath incorporating a 1.3mm endoscope with a working channel, through which a 0.4 mm laser fiber is introduced. The fetoscope is advanced into the posterior urethra, the valves are identified and fired using contact diode energy. The mean time of operation is 24 minutes. Similar results reported by Ruano et al in a series 23 patients [94]. Although, this sophisticated technique is thought to be experimental, it is associated with low complication rates, and may accompanied with better outcomes than other techniques, such as bladder shunting [93]. However, larger series are needed to support this dispute.
Recurrent UPJO

Although Anderson-Hynes dismembered pyeloplasty is a reliable method of treating patients with UPJO, with success rate more than 94% [95], in a minor number of cases, a reoperation should be taking into account.

Management of recurrent UPJO, includes a number of interventional and surgical approaches, such as endopyelotomy [96], and laparoscopic and robot-assisted laparoscopic pyelotomy [97].

Recently, Parente et al [95], showed than modified percutaneous endopyelotomy is a reasonable compelling technique to treat recurrent UPJO. The technique in brief includes at first a cystoscopy and a retrograde pyelography for evaluation of the anatomy of the affected upper urinary tract. After introduction of 0.014-inches guidewire into the pelvis, a high pressure 5mm balloon is inserted and inflated at 14 atm over the guide-wire and left in place. Then, a miniperc is performed using the Sedlinger technique. Endopyelotomy is performed with a monopolar hook electrocautery (40W, power cut incision). Renogram at 3 months showed renal function improvement in 7 renal units. Although the number of patients was small, this procedure seems to be adequately effective.

Conclusions

There is an ongoing evolution in the endoscopic management of a wide spectrum of urological abnormalities in children, with a parallel propensity of decrease in open surgery. However, a substantial number of endoscopic techniques should be established with evidence-based studies. In addition, these innovative techniques may improve factors such as the elimination of hospital stay and the reduction of operative time and of postoperative complications. Furthermore, the technical skills in these sophisticated techniques should be improved by continuous training.

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