The role of laparoscopy in paediatric and adolescent gynaecology

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Abstract

Paediatric and adolescent gynaecology is a narrow field of medicine dealing with the diagnosis of and treatment of gynaecological diseases from the neonatal period to sexual maturity. The current trend in surgical gynaecology in the paediatric population is to minimise the degree of invasiveness of diagnostic and therapeutic procedures. This contributes to reducing the number of complications and the risk of infertility. Laparoscopic procedures are a challenge for paediatric surgeons and gynaecologists, not only because of the age of treated patients, and anatomical and physiological differences between different age groups but also because of the complexity of the pathology, the differentiation of cancer tumours, and the presence of congenital developmental defects.

Key words: laparoscopy, congenital defects, ovarian torsion, ovarian cyst, paediatric gynaecology.

Introduction

Laparoscopic surgery has many well-documented advantages, such as better visualisation of the surgical field, less postoperative pain, shorter hospitalisation time and convalescence, lower risk of postoperative adhesions, and better cosmetic results. The dynamic development of minimally invasive techniques has made them widely used in every field of surgery for adults and children. Laparoscopic procedures have become a widely accepted procedure in the field of gynaecology [1]. In paediatric and adolescent surgical gynaecology, the most important aspects concern the correct diagnosis and treatment of acute conditions such as adnexal torsion, treatment of cysts and tumours of the ovary or fallopian tube, and surgical methods of correcting congenital genital defects. Operators performing paediatric gynaecological procedures should take into account the anatomical differences that occur in girls compared to adult women, such as lower height, thinner abdominal wall around the navel, higher upper blad-der edge, relatively smaller uterine fundus, extended cervix, longer fallopian tube, small volume, and higher ovary position. Special attention should be paid to the prevention of fertility preservation in patients operated on due to adnexa pathology or congenital defects [2]. The risk of postoperative adhesion formation in minimally invasive laparoscopic procedures is minimised compared to open surgery, which is particularly important for preserving future fertility [3]. At present, the age of a child does not limit the possibility of using laparoscopic surgery, due to constant technological progress, minimisation of instruments, and growing experience of operators. Trocars and tools with a diameter of up to 1.7–2 mm enable laparoscopic procedures even in newborns [4].

Ovarian cyst surgery

Ovarian cysts are the most common pathology of adnexa in all age groups in the paediatric population. Histopathological examinations of lesions from adnexa usually reveal non-cancerous cysts (benign

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or functional ovarian cysts), which are estimated to account for about 58% of cases, and non-malignant tumours [1, 4]. Malignant tumours account for about 8% of all cases [5].

Although ovarian pathologies in children are rare, they differ in aetiology and clinical course and are most often associated with acute or chronic abdominal pain. Ovarian cysts can still be diagnosed in foetal life and have a prevalence of 1 per 1000 female foetuses. The mechanism responsible for the formation of ovarian cysts in foetuses involves an unregulated response of ovarian follicles as a result of the influence of the foetus' own hormones (FSH), mother's hormones (oestrogen), or placenta's hormones (hCG) [6]. In the majority of prenatal diagnosed pathologies, their involution after birth occurs. In a meta-analysis consisting of 92 non-randomised studies, which included 380 ovarian cysts diagnosed in 365 foetuses, the rate of cyst involution after delivery during the observation period was 46%. This rate decreased with the increase of cyst size. Spontaneous involution decreased with an increase in the size of the cyst from 17% to 21% for cysts with a diameter of 60 mm or more [6]. In some cases, ovarian cysts may persist throughout the first year of life, but their incidence is higher in the age group between 8 and 15 years of age [7]. Insufficient involution of the follicles in the ovary can lead to the formation of large cysts and thus a higher risk of complications in the form of bleeding into the interior of the cyst, sudden rupture of the cyst with massive bleeding into the abdominal cavity, and torsion and autoamputation of the cyst or ovary [6, 7].

Ultrasonography is the most important and non-invasive diagnostic tool for cyst evaluation. A number of criteria with particular reference to the size of the cyst or tumour, echogenicity, and the presence of solid components of the cyst may facilitate pre-operative diagnosis [8, 9]. Cysts containing a solid component with concomitant elevated levels of alpha-fetoprotein (AFP), human chorionic gonadotropin (β-hCG), foetal-cancer antigen (CEA), alkaline phosphatase, or cancer antigen 125 (CA-125) and no regression in the size range of the cyst during a 3-month ultrasonographic observation arouse suspicion of malignant changes and require surgery [7, 9]. In addition to the oncological indications, patients whose cyst diameter has not decreased in ultrasound over a period of 3 months, patients with recurrent pain, signs of intra-abdominal compression, and intestinal passage disorders, or patients with 'acute abdominal' symptoms are eligible for ovarian cyst surgery [7].

Ovarian cyst treatment options include cyst aspiration or resection, fenestration, cyst unroofing, cysto-ovariectomy and cysto-adnexectomy [7, 10]. In all cases, the aim should be to save an organ as much as possible. The choice of method of cyst surgery depends on its character and size, the presence and type of accompanying symptoms, and on the experience and profession of the operator. It should be noted that the surgical treatments on adnexa in the paediatric population are performed by gynaecologists, paediatric surgeons, and general surgeons [10]. Aspiration of the contents of the cyst may be performed in the case of cysts that are detected accidentally during another laparoscopic procedure or in the case of large cysts that restrict the operating space [7]. In the case of functional ovarian cysts, simple aspiration and fenestration have a higher risk of recurrence than a complete cyst resection [1]. Large cysts are aspirated by some operators under the control of ultrasonography because of the direct visualisation of the cyst itself before laparoscopic cystectomy [7, 10].

The most popular method of cyst content aspiration described in the literature is peritoneal aspiration of an ovarian cyst under direct control of laparoscopy with cyst wall resection and getting it out with an endo-catch. However, this is not a method that guarantees that the contents of the cyst will not leak into the abdominal cavity [9]. According to the published literature the rates of intraoperative leakage of ovarian cyst contents during laparoscopic procedures range from 0% to 100% [9]. However, complications such as peritonitis or adhesions leading to loss of fertility in the paediatric population are minimal [11]. Nonetheless, there is another aspect of complications after extracting the contents of the cyst during the procedure, which is associated with the possibility of implanting malignant tumours into surrounding tissues. Although the risk of leakage cannot be completely eliminated, an exploratory trend is observed to minimise cyst leakage during laparoscopy [12].

Benign neoplasms, such as mature teratomas, which account for about 50% of benign ovarian cancers in girls and young women [10], require surgical removal as the primary treatment for these lesions. The preferred procedure for the resection of benign

ovarian lesions is their removal while saving ovarian tissue in order to maintain the highest possible function of the endocrine and reproductive systems. Ovarian tumour enucleation is recommended, which involves gentle removal of the tumour capsule from a healthy ovarian parenchyma either bluntly or sharply using preparation scissors and then evacuating the lesion by means endo-catches [13]. In the case of patients who are suspected during laparoscopic surgery of a malignant tumour, an intraoperative biopsy should be performed with histopathological evaluation of the ovarian lesion [1]. Only after receiving the final histopathological examination can an appropriate decision be made on the extent of the necessary operation. If a malignant process occurs, it is connected with the necessity to carry out a second procedure to open the abdominal cavity and perform an operation guaranteeing radicality and thus a chance of survival of the treated patient [14].

Adnexal torsion

Ovarian torsion occurs most often in the first three decades of life and is usually considered as an indcator of female reproductive age [13]. Only 15% of cases of torsion occur in infancy and childhood [15]. Although torsion of the ovary is a rare problem, representing only 2.7% of causes of acute abdominal pain in the paediatric population, it should be considered in the differential diagnosis in children with acute abdominal pain or pelvic mass [16]. The golden standard in the diagnosis of ovarian torsion is ultrasonography, which provides direct and rapid evaluation of ovarian anatomy and perfusion in a non-invasive way [17]. During Doppler ultrasound examination, visible lack of flow in the ovarian artery, enlargement of ovarian size, peripheral position of follicles, abnormal location of ovaries and fallopian tubes compared to the uterus, and the presence of free fluid are helpful characteristics of torsion of adnexa [18, 19]. Although ultrasonography is the method of choice for the imaging of torsion of adnexa, unfortunately it is not a definitive diagnosis [16, 19]. The use of the Doppler function is of limited value due to the presence of double vascularisation of the ovary, which makes it impossible to explicitly exclude torsion [19]. If ultrasonography does not confirm torsion of the adnexa and in clinically unclear situations, diagnostic laparoscopy provides the advantage of earlier intervention and may improve

the results in preserving healthy ovarian tissue and maintaining fertility function [20, 21]. Traditional treatment of ovarian torsion consists of the removal of ovaries due to possible embolisation after the detorsion. Nowadays, in paediatric gynaecology, the aim is to save the organ even in the case of a twisted ovary. Laparoscopic access offers a combination of diagnostic and therapeutic intervention with direct detorsion, the possibility of collecting specimens for histopathological examination in doubtful cases, or the possibility of ovarian resection in the case of total ovarian necrosis [13].

In most cases, adnexal torsion coexists with the pathology of the ovary or fallopian tube. Basically, these are benign lesions such as ovarian cysts, haemorrhagic cysts, or functional cysts and benign tumours [21]. Cases of isolated adnexal torsion without coexisting pathology are also described in the literature [20, 22]. Surgical treatment options for torsion include ovarian derotation, derotation with oophoropexy, and ovarian and/or fallopian tube resection [22].

In the case of the coexistence of ovarian pathology and torsion, it is justified to perform derotation of adnexa and to perform an additional procedure, such as cystectomy or tumourectomy, to prevent relapse [21]. The frequency of coexistence of adnexal torsion and malignant tumours in the paediatric population is only 0.5% to 8% of cases [5, 23], and the fear of malignant causes is often the reason for the decision to perform oophorectomy during the treatment process [22]. The torsioned ovary is often enlarged and discoloured, making the assessment for the occurrence of cancer difficult. The cancer risk should not be used to justify ovarian resection due to the generally low incidence of ovarian malignancies in the paediatric population. Only if there is clear clinical evidence of malignancy should ovarian resection be considered [22]. Occasionally, torsioned adnexa may be highly oedematous and brittle, and the performance of cystectomy or tumourectomy may result in further damage to the ovarian tissue, bleeding, and an urgent need to resect the ovary instead of saving its tissue [24]. In these cases, the derotation itself should be considered to protect the ovaries and, after 6–12 weeks, imaging examinations should be carried out, followed by cystectomy if required [18, 22]. Simple cysts often undergo spontaneous resorption after 6–8 weeks [24]. The main goal of surgery in adnexal torsion is to protect

the ovarian tissue to maintain fertility. The derotation itself should be considered even when the ovary appears to be necrotic (blue-black), because there is no certain clinical evaluation method to predict ovarian viability. Only collecting specimens and their microscopic evaluation necessitate the diagnosis of necrosis. There are reports demonstrating that performed histopathological examinations revealed the presence of live ovarian tissue after a torsion, despite macroscopic evaluation by the surgeon as necrotic tissue [25]. The blue-black appearance of the ovary may be secondary to the lack of flow in the venous vessels, and not a result of ischaemia. Such a state is explained by double inflow of blood to the ovary from the uterine and ovarian vessels, which provide better protection against complete ischaemia [18, 26].

An adnexal torsion is a surgical emergency in which urgent diagnostic and therapeutic laparoscopy with a procedure saving the ovarian parenchyma should be performed [21]. The factor in favour of laparoscopy is related to lower risk of postoperative adhesions formed in the pelvis, which may also be one of the causes of infertility [3].

The rate of recurrence of the torsion of adnexa is about 2–18% and may be even higher for isolated torsion of adnexa [22, 24, 27]. Unfortunately, the benefits of oophoropexy are controversial. Some authors believe that oophoropexy may disturb the function of the ovaries, and the altered anatomical relation between the ovarian follicles and the fallopian tube may affect fertility [18, 24, 27]. Oophoropexy should be considered in the case of isolated or repeated torsion of adnexa, the presence of a single gonad, or an elongated ovarian ligament [18, 21, 27]. Isolated torsion of the ovary or fallopian tube is much less frequent than torsion of adnexa. Torsion of the fallopian tubes is almost always associated with the pathology of the fallopian tubes. The risk factors of torsioned fallopian tubes include endometriosis, adhesions, and fallopian tube pathologies such as hydrosalpinx, haematosalpinx, cancer, or congenital defects. The incidence of isolated torsion of the ovary or fallopian tube is difficult to determine; such cases are rarely described in the medical literature [28].

Gonadectomy

Gonadectomy is indicated in many gender differentiation disorders associated with the Y chromosome to reduce the associated cancer risk [29, 30]. In patients with intra-abdominal gonads, laparoscopy plays a very important diagnostic role in locating the gonads and determining the pelvic anatomy, while assuming a therapeutic role in the removal of dysgenetic gonads and residues from Mullerian ducts. Before the era of laparoscopy, the localisation of intra-abdominal gonads was difficult because various imaging methods (including ultrasonography, computed tomography, and even magnetic resonance imaging) had low diagnostic sensitivity. Thus, laparotomy and bilateral gonadectomy were the traditional procedures for people with impaired gender differentiation [29, 31]. At present, laparoscopy provides good visualisation of the surgical field, which enables accurate pelvic control and accurate location of gonads.

In cases when the location of gonads is difficult to identify, their situating is aided by revealing the vessels supplying gonads and then the gonadal tissues. The gonadectomy is performed after the ureter is revealed and the precise localisation of the course of the ureter and fallopian tubes is provided, to reduce the risk of their damage [29].

In the analysis conducted by Calvo et al., which included 168 cases of laparoscopic gonadectomy, the average surgery time was 70 min. No conversions or intraoperative complications were reported. Postoperative complications were demonstrated only in one study, where the umbilical port infection was present (2% (1/50)) in one case and pelvic abscess (2% (1/50)) in the other. Both cases were treated conservatively with antibiotics [29]. In the material presented, the authors emphasise the advantages of a minimally invasive procedure, which is associated with lower risk of mid- and postoperative complications, faster recovery, and good cosmetic results. The latter aspect is particularly important for patients with gender differentiation disorders, who require confirmation of their good body image and self-esteem [29].

Congenital defects

Vaginal and/or uterine developmental malformations in girls are relatively rare, with an estimated frequency of 0.4–10%. These are only estimates because many of the defects are not recognised due to asymptomatic course [32–34]. During the embryonic period, female genital organs are formed from two

Mullerian paramesonephric ducts, which, as a result of differentiation, form the oviduct, uterus, cervix, and upper vagina. Any abnormalities in the formation and subsequent connection of these ducts lead to the formation of various developmental malformations. For example, the absence of one of these ducts leads to the formation of the uterus unicornis. An incomplete fusion of the Mullerian duct leads to uterus bicornis or uterus septus. No connection of the Mullerian ducts leads to the formation of uterus duplex. Currently the classification system developed in 1988 by the American Society for Reproductive Medicine, based on the anatomical image established by imaging, is valid. On this basis, the disorders were classified in seven clinical groups [35]:

1. Hypoplasia or agenesis:
   a) vaginal,
   b) cervical,
   c) of uterine body,
   d) of fallopian tube,
   e) mixed;
2. Unilateral abnormalities – anomalies caused by the lack of elongation of one of Mullerian ducts:
   a) residual uterine horn communicating,
   b) non-communicating residual horn,
   c) inactive residual horn,
   d) non-communicating residual horn;
3) uterus duplex – disorders caused by the complete lack of connection of the Mullerian ducts;
4) uterus bicornis – disorders caused by an incomplete fusion of Mullerian ducts:
   a) total,
   b) partial;
5) uterus septus disorders caused by the lack of septum resorption occurring after Mullerian ducts are connected:
   a) total,
   b) partial;
6) arcuate uterus;.
7) developmental anomalies related to the use of diethylstilbestrol.

In most cases, congenital developmental Mullerian duct anomalies (MDAs) occur in women with properly formed and functioning ovaries as well as properly formed external genitals. Initially, these anomalies do not reveal any clinical signs and are therefore neither diagnosed nor recognised early. It is only at the time of puberty that they are manifested by no menstruation with or without cyclical pain. The occurrence of uterine defect leads to impaired fertility and many obstetric complications, and proper clinical diagnosis and surgical treatment adapted to the type of defect, in the vast majority of cases, enables normal sex life and improves the prognosis of fertility and the possibility of carrying to term pregnancy [36]. Correct treatment can be performed if the defect is strictly defined; therefore, the first and key stage of surgery involves good visualisation of pelvic anatomy and clarification of anomalies of the uterus, appendages, and cervix. This is very important because the type of surgery and prognosis after surgery differ depending on the type of defect [37]. In the surgical treatment of congenital anomalies, as well as the choice of the method of correction of the defect, the appropriate time of surgery should be considered. For example, in the case of vaginal agenesis (type I according to the American Fertility Society) in Rokitansky-Kuster-Hauser syndrome and in androgen insensitivity syndrome, the surgical treatment related to vaginal formation should be carried out immediately before the start of sexual contact, and therefore it seems unjustified to perform surgery on younger girls [38].

The formation of a new vagina can be performed by surgical creation of a tunnel between the bladder and rectum using a skin graft (McIndone method), use of the intestine, peritoneum, amnion, allogenic epidermis, autologous cheek mucosa, or cultured invitro autologous vaginal tissue [39]. Currently, the most popular methods of laparoscopic neovagina formation are Vecchietti´s and Davydov´s methods.

The Vecchietti operation involves continuous pulling up of a dilator placed in the space of the newly created vagina and fixed on special traction threads carried from the perineum to the pelvis and out through the abdominal wall. The traction mechanism enables the dilator to permanently apply pressure to adjacent tissues and to produce and lengthen the vesico-rectal space for the vagina, which, after about 7–8 days, reaches a length of about 7–8 cm [40, 41]. Laparoscopic Vecchietti surgery is effective because the neovagina is formed with normal anatomy, histomorphology, and functionality [42]. Good functionality results from the fact that neovagina is covered with typical vaginal epithelium shortly after surgery, and functional vaginal length is achieved within a few days [41]. The anatomical rate of effectiveness is as much as 97–99%, and the neovagina usually maintains the right size even in the absence

of regular sexual intercourse and does not require long-term dilatation [43]. In addition, this method eliminates the need for foreign tissues such as skin, peritoneum, and intestine that cause visible scars [41]. The risk of intraoperative damage to the ureter, rectum, or bladder is 1–1.8% [43]. However, the formation of a neovagina can change the previous anatomy, modifying the balance of the pelvic floor and leading to a change in the angle of the urethra, lack of support, and excessive mobility. This may cause urinary incontinence [44]. Many authors emphasise that the modified Vecchietti laparoscopic technique is a simple, fast, effective, and low-risk procedure that allows the creation of a neovagina in the right axis, of appropriate size, and retaining excretion capacity. It allows women with congenital vaginal aplasia to start normal sexual activity with proper effect (Table I) [45–59].

Davydov's operation involves the mobilisation of the bladder peritoneal walls, pelvic wall peritoneum, and peritoneal sigmoid. The mobilised peritoneal parts are pulled and led out through the newly created vesico-rectal space and then sutured to the vaginal vault. A special dilator is used to maintain patency of the vaginal canal [36]. Laparoscopic Davydov's surgery is satisfactory due to the fact that the length of the vagina is about 8.5 ±1.6 cm [60], and the results of vaginoscopy and neovaginal biopsy after 6 months show the presence of a typical vaginal epithelium [61]. In addition, satisfaction from sex life is 92–93% [60]. However, there is an increased risk of intraoperative bladder or bowel injury (3.8%) and postoperative infections [62]. Long-term complications include the risk of vaginal constriction (5.1%) and the risk of vaginal collapse due to the modifying effect of this method on the anatomical structure of the pelvis [62].

Table I. Results of laparoscopic formation of neovagina using the Vecchietti technique

Author	Number of patients	Mean age [years]	Percentage of complications (amount)	Vaginal length [cm]	Sexual satisfaction (FSFI)	Functional and anatomical result	Follow-up
Adamiak-Godlewska 2019 [45]	15	22.06 ±5.13	0	7 ±1.2	93%	–	8.02 ±3.43 years
Baptista 2016 [46]	9	22.2	0	8.1	51.11 – 95.83%	–	53.2 months
Csermely 2011 [47]	23	–	13.04% (3)	8.8 ±1.1	83.61 – 94.17%	–	–
Fedele 2010 [48]	9	–	0	7.4 ±0.6	–	89%	4 years
Brucker 2008 [49]	101	20.27 ±5.9	6.93% (7)	8.9 ±1.6	–	8 patients with dyspareunia, 4 required vaginal dilatation	3–53 months
Borruto 2007 [40]	86	16–34	0	7.49 ±0.79	–	98.1%/100%	34–64 months
Fedele 2000 [50]	51	16.9	5.88% (3)	≥ 6	–	98.1%/100%	6 months
Borruto 1999 [51]	7	–	0	7.49 ±0.79	–	NR/100%	5 years
Cezar 2014 [52]	53	25	3.77 % (2)	≥ 6	–	79%/94%	1–5 years
Gauwerky 1992 [53]	5	20.4	0	9.8	–	NR/100%	NR
Keckstein 1995 [54]	9	21	22% (2)	10	–	NR/100%	NR
Khater 1999 [55]	6	26.3	17% (1)	6,5	–	NR/100%	6 months
Giacalone 1999 [56]	7	22.7	0	7	–	NR/86%	12.8 months
Keckstein 2008 [57]	8	21.9	0	9,6	–	NR/87.5%	40.3 months
Folgueira 2006 [58]	18	20.1	16.67% (3)	11.3	–	NR/94.44%	6–60 months
Rall 2014 [59]	241	20.5	0	9.5	83.33%	83.33%/100%	11–141 months

NR – not reported.

Laparoscopy is a valuable diagnostic and therapeutic tool in the presence of congenital malformations of female genital organs. During laparoscopy, it is possible to diagnose and evaluate the possibility of treating residual uterine horns (type II according to the American Fertility Society) and simultaneous or postponed procedures to correct existing malformation [39]. The additional horn may have a uterine cavity with a functional endometrium and in some cases may be connected to the normal uterine cavity. Of utmost importance from a clinical point of view is the residual horn not communicating with the active endometrium. Lack of communication with the normal uterine cavity leads to the formation of haematomas, which results in chronic pelvic pain and dysmenorrhoea; it can also lead to residual horn torsion or fallopian tube torsion. These patients also have a higher rate of endometriosis, ectopic pregnancies, miscarriages, and premature births if they manage to become pregnant [63, 64]. The indication for surgery is the presence in the residual horn not communicating with the active endometrium. Surgical treatment is not recommended in cases of residual horn devoid of endometrium. The procedure of choice is laparoscopic hemi-hysterectomy of the residual horn, even if it is complicated by a haematoma, haematosalpinx, or ectopic pregnancy [36, 65]. When performing the procedure, a few details should be accounted for: first, there is no strict boundary between the uterus and the base of the horn. In this case, hysteroscopy can be helpful by highlighting the border of the uterus and horn. Opening the uterine cavity may affect future fertility [63]. The myometrium is resected at the junction of the horns and then cut using bipolar coagulation or laser [36]. In addition, the fallopian tube from the residual horn should be removed along with it to avoid tubal pregnancy, but the function of the ovary should be preserved [66]. Laparoscopic hemi-hysterectomy of the residual horn should be performed as early as in adolescence to prevent complications such as infertility, ectopic pregnancy or residual horn pregnancy, or torsion and detachment of the horn [65]. Possible complications are typical for the laparoscopic technique used in surgical gynaecology [36].

In the case of uterus duplex (type III according to the American Fertility Society), the standard of surgical treatment for correction is laparoscopic metroplasty using the Strassman method, which is also used for the correction of uterus bicornis (type IV according to the American Fertility Society) [67].

The complete clinical picture of this defect includes the presence of two uteri with two cervical canals connected in the lower parts of both uteri, each with one fallopian tube. The vagina can be single or double, divided by an elongated septum [36]. Starssman metroplasty consists of making a connection between the fundus of the uterus and the uterine cavity, leaving the cervix unchanged. After the introduction of trocars into the abdominal cavity, the first step of the procedure is macroscopic assessment of the ovaries and fallopian tube and the visualisation of adhesions between the uterus and other organs. The potential adhesions should be released. In the next step, an incision is made along the middle parts of the separated uterine cavities towards the point of their connection, and then the incision expands towards the fallopian tubes. The endometrial cavity of the two uteri is opened with cold scissors. Then, single sutures are placed on the posterior and separately on the anterior wall of both uteri, bypassing the endometrium. The sutures are joined by connecting the opposite edges of the uterine muscle and thus forming one uterine cavity. Finally, the uterine membrane is closed with a continuous suture [67–69]. The technique of suturing the layers of the uterus is an important aspect that improves the functional result of the operation. When stitching myometrium, the edges must be joined without tension and haematomas. These precautions are necessary to reduce the likelihood of decreased uterine wall strength, which may have negative consequences during pregnancy and delivery [70]. Some authors perform laparoscopy, 3 months after metroplasty, as part of the "second-look" follow-up along with hysteroscopy and assess the uterine cavity and the formation of adhesions [67, 69]. During hysteroscopy, the susceptibility of the uterus to increased intrauterine pressure up to 150 mm Hg is also assessed to confirm whether the uterine cavity is able to withstand such pressures, which occur during pregnancy and delivery [67, 69]. The most important advantage of laparoscopic metroplasty is the reduced formation of adhesions in the abdominal cavity, which play an important role in the aetiology of secondary infertility, especially in fallopian tube function. The cases of laparoscopic Strassman surgery described in the literature show restoration of the uterus anatomy, even fusion of uterine walls with good scar integrity, minimal adhesion formation, less blood loss, and shorter stay in the hospital [69, 71].

The pathology of uterus bicornis (type IV according to the American Fertility Society) consists of the formation of two communicating uterine cavities and a common single cervix and vagina. A muscular septum is present inside the uterus, which manifests itself as a hollow in the uterine fundus. If the septum is limited to the corpus uteri, then a partially bicornis uterus is formed, which usually does not require surgical treatment and causes minor fertility disorders. The distinction between a partially bicornis uterus and a complete uterus with a septum is an important element in the diagnostic process because this diagnosis implies treatment. Usually the correct diagnosis can be made using ultrasonography or MRI. In ambiguous situations, the diagnosis should be extended by laparoscopy, which allows for a reliable differentiation between a partially bicornis uterus and uterus septus. The partial bicornis uterus is characterised by the presence of two horns, whereas the fundus of uterus with a septum looks like a normal fundus of uterus [36]. The uterine septum requires surgery because hysteroscopic dissection of the septum definitely improves reproductive results. In contrast, the bicornis uterus and partial bicornis uterus rarely require surgical reconstruction. Laparoscopic metroplasty should be reserved only for women who have a habitual miscarriage or late pregnancy loss, premature births, or who do not have other etiological factors causing pregnancy loss. In such cases, the Strassman procedure can be initiated. The aim of the operation is to obtain a single channel from the cervix to the uterine cavity. The connection of both cavities is achieved by wedge-shaped septum resection [69, 72]. The method of the choice for treatment of the uterine septum is hysteroscopic metroplasty using a laser or electrical surgical instruments with using laparoscopy. Laparoscopic visualisation helps reduce the risk of uterine perforation during the cutting of the septum. The septum intersection is considered complete when the hysteroscope can be moved freely from one outlet of the fallopian tube to the other without any obstacles.

Laparoscopy additionally plays an important auxiliary role during hysteroscopic removal of the uterine septum (type V according to the American Fertility Society). The procedure of choice for treatment of uterine septum is hysteroscopic metroplasty using microscissors, electrical surgical, or laser with simultaneous use of laparoscopy. Laparoscopic visualisation helps reduce the risk of uterine perfo-

ration during septal incision. The septal incision is considered completed when the hysteroscope can be moved freely from one fallopian tube outlet to another without any obstacles, which enables visualisation by laparoscopy [36].

The combination of hysteroscopy and laparoscopy is a gold standard not only in the assessment of the uterine septum but also in the evaluation, classification, and treatment of congenital uterine anomalies, especially in young women with difficulties in getting pregnant. Moreover, laparoscopy is also an important element of infertility diagnostics and provides the possibility to treat any concurrent pelvic pathology [37, 73–75]. The combination of these two methods certainly enables quick and complete identification of most of the causes of infertility [76].

Endometriosis

Endometriosis is a chronic gynaecological disease, most often diagnosed in women of reproductive age, which consists in the occurrence of active glands and endometrial stroma outside the uterine cavity, within the ovaries, fallopian tubes, in the pouch of Douglas, in the bladder, or other abdominal organs. It is often associated with chronic abdominal and pelvic pain [77]. Chronic pelvic pain in paediatric and in adolescent gynaecology occurs in 19–73% of young patients [78], who, during diagnostic laparoscopy, are most often diagnosed with the following: endometriosis, postoperative adhesions, ovarian functional cysts, reproductive malformations, appendicitis, or no confirmed pathology [79–81]. Although about 2/3 of women with confirmed endometriosis have their first symptoms before the age of 20 years [82], the real incidence of endometriosis in adolescents is not yet accurately estimated [83]. It is known that endometriosis affects 73% of adolescents and adult women with a history of primary dysmenorrhoea [84], while 62% of adolescents with chronic pelvic pain or dysmenorrhoea are diagnosed with endometriosis during diagnostic laparoscopy [85, 86]. The incidence of endometriosis in girls with chronic pelvic pain increases with age [79], while there is no correlation between the progression of endometriosis and age [87], and pelvic pain in girls with endometriosis does not correlate with the clinical stage of the disease – it can show high intensity in both minimal and high-degree endometriosis [79]. In addition, the incidence of endometriosis in the

paediatric population increases significantly from 5% to 40% in the presence of defects in the reproductive organs resulting from congenital anomalies in the development of the Mullerian ducts, leading to obstruction of the reproductive organ and disturbance of menstrual drainage [79, 83, 88]. Laparoscopy is the gold standard in the assessment of endometriosis, and in accordance with the guidelines of the American College of Obstetricians and Gynaecologists (ACOG) of 2018 it should be used in the case of persistent pain despite the use of cyclic two-component contraceptive therapy and NSAIDs for a period of 3 months [83, 89]. Therefore, laparoscopy is the last diagnostic stage in chronic pelvic pain in the paediatric population. To diagnose endometriosis, glands and uterine stroma outside the endometrial cavity are required along with the confirmation of their presence in histopathological examination after biopsy of the suspect site [83, 86]. Laparoscopy provides the above conditions and, in combination with histopathological examination, allows unambiguous confirmation of endometriosis [79, 80, 83, 90]. The appearance of endometriosis may be different in adolescents than in adult women because the endometriotic changes in adolescents have a laparoscopic picture atypical in nature, different from the changes seen in adult women. In the adult type of endometrial implant, typical "powder-burn" lesions are common, whereas reddish, clear/polypoid, or even vesicular lesions are more frequent in adolescents [79, 80, 83, 86, 90–92]. The correlation of histological and macroscopic findings in peritoneal endometriosis by Strehl *et al.* suggests that lesion colour in endometriosis is associated with lesion age, gland pattern, and gland content rather than with biologic activity. Therefore, the colour of the implants may be different [93]. Endometrial implants can be difficult to identify, especially for operators who do not know the nature of endometriosis in adolescents [79, 80, 83, 86, 90, 92]. Endometriosis can only be diagnosed by visual inspection during laparoscopy, ideally confirmed by histology [85]. However, some authors recommend that specimens for histopathological examination should be taken from lesions suspected of endometriosis because there is a high percentage of results of false positive endometriosis diagnoses made only during visual identification [83, 86, 94]. Other lesions suspected of endometriosis should be destroyed, removed, or excised at the time of the first laparoscopy [95]. In the case of a normal macroscopic image during diagnostic laparoscopy in the paediatric population with chronic pelvic pain syndrome, it is recommended that several biopsies be collected from sites typical for the location of endometriotic lesions (pouch of Douglas peritoneum, utero-sacral ligaments, and ovarian fossa) [79]. To improve the visualisation of changes in laparoscopy, the technique of image enlargement and pelvic filling with saline and "immersion" of optics approaching the target point can be used [95].

The benefits of laparoscopy include confirming the presence or absence of endometriosis and identifying possible other causes of chronic pain such as adhesions. Laparoscopy should be avoided for the sole purpose of diagnosis without attempting treatment [93]. It should be added that laparoscopy also gives the possibility of treating endometriosis by laser vaporisation, ablation, monopolar and bipolar electrocoagulation, or resection of visible implants and the release of adhesions in the case of adhesive disease [79, 83].

Technical aspects of laparoscopy in paediatric gynaecology

Many potential traps in paediatric and female gynaecology result from anatomy and physiology, and they pose technical challenges in the application of laparoscopy. The treatment stages themselves are often similar to those of adult women, although they require appropriate planning and consideration of unique characteristics for the paediatric population.

Traditional techniques for laparoscopic access in paediatric gynaecology include Veress needle access or minilaparotomy and direct insertion of an optical trocar, under visual control, into the peritoneal cavity (the Hasson method) [96]. As in adult women, the preferred site for access to laparoscopy in gynaecology is the combination of abdominal wall layers at the base of the umbilical cord where all layers are together the thinnest. However, two unique features of the paediatric population should be considered. Firstly, the integrity of the abdominal wall tissue varies according to the age of the child, and there is considerable limpness and elasticity in the abdominal wall of newborns and infants, which gradually increases its tension and strength of the fascial wall as they grow older [26]. This fact should be taken

into account during the insertion of trocars to avoid the risk of damage to large vessels and internal organs. Secondly, the distance from the umbilical cord to the aorta and its foramen may be significantly smaller in paediatric patients, which increases the risk of potential damage to the aorta, inferior vena cava, or common iliac vein [27, 28]. When setting subsequent trocars, the length and the width of the abdomen and pelvis must be considered. The ports located in the lower quadrants should be lateral to the vagina and rectum and to the lower abdominal vessels. This allows for proper ergonomics and good access to the pelvic organs, which improves the comfort of the operator and reduces the risk of complications. Trocars with the smallest possible diameter should be used due to the increased risk of hernias, which are conditioned by a thinner abdominal wall than in the adult population.

The process of abdominal insufflation also requires modification in the paediatric population. The maximum possible pressures are 6 to 8 mm Hg in infants, 8 to 10 mm Hg in young children, and 10 to 15 mm Hg in older children and adolescents. However, the age limits are not precisely defined. Potential contraindications for laparoscopic surgery, and especially for pneumoperitoneum, are relatively few in number and are generally associated with the occurrence of serious cardiopulmonary disease and intolerance to external venous pressure by the pressure exerted in the abdominal cavity. In addition, existing chronic lung disease with an elevated diaphragm may reduce respiratory volume and oxygenation. Except for chronic lung disease or unadjusted congenital heart disease, paediatric patients regularly tolerate pneumoperitoneum within established pressure limits.

Summary

It should be stressed that laparoscopy is widely used in diagnostics and the treatment of pathologies found in paediatric and adolescent gynaecology. Laparoscopic procedures ensure a safe course of surgery and minimise intraoperative and postoperative complications. In addition, they offer the possibility of a cost-effective therapeutic management but at the same time require an exceptional and cautious approach with particular emphasis on the preservation of reproductive functions and fertility and the anatomical differences and physiological conditions of the pelvic organs in children of different ages.

Conflict of interest

The authors declare no conflict of interest.

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