Minimally invasive surgery in pelvic pain: from a gynecological perspective

Salih Yilmaz\textsuperscript{1,}\textsuperscript{A}, Nura Fitnat Topbas Selcuki\textsuperscript{2,}\textsuperscript{A}, Taner Usta\textsuperscript{1,3,}\textsuperscript{A}, Ahmet Kale\textsuperscript{4}

\textsuperscript{1}Department of Obstetrics and Gynecology, Altunizade Acibadem Hospital, Istanbul, Turkey; \textsuperscript{2}Department of Obstetrics and Gynecology, Istanbul Sisli Hamidiye Efaf Training and Research Hospital, Health Sciences University, Istanbul, Turkey; \textsuperscript{3}Department of Obstetrics and Gynecology, Altunizade Acibadem Hospital, Mehmet Ali Aydinlar Acibadem University, Istanbul, Turkey; \textsuperscript{4}Department of Obstetrics and Gynecology, Istanbul Kartal Lufi Kirdar Training and Research Hospital, Health Sciences University, Istanbul, Turkey

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\textbf{Correspondence to:} Taner Usta. Department of Obstetrics and Gynecology, Altunizade Acibadem Hospital, Istanbul, Turkey; Department of Obstetrics and Gynecology, Altunizade Acibadem Hospital, Mehmet Ali Aydinlar Acibadem University, Istanbul, Turkey. Email: drtanerusta@gmail.com.

\textbf{Abstract:} This review on the minimally invasive surgical management of chronic pelvic pain (CPP) was constructed from a synthesis of our experience and the literature. Following a description of CPP and its causes, a general introduction to minimal invasive approaches applied in the treatment of CPP from a gynecological perspective was given. Then the surgical management of several most important pelvic pathologies causing CPP was explained in detail. Not only gynecological, but also pelvic neurological pathologies were discussed in this review. A neuropelveological approach to CPP was also included. An extensive literature research was conducted by the authors and chosen studies were included based on strength and relevance. Due to its multifactorial etiology, CPP has been a challenging subject for clinicians. Because of the dynamic nature of surgical innovations especially in the field of minimal invasive surgery, a variety of techniques have been developed and tested in the treatment of CPP and we tried to cover the most important ones. We aimed to reflect the advantages and disadvantages of the surgical management of CPP according to different etiologies and also according to the application of different surgical techniques such as the use of the robotic platform. An emphasis was given to the importance of a multidisciplinary approach.

\textbf{Keywords:} Pelvic pain; neuropelveology; minimally invasive surgery

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Pelvic pain

Pelvic pain is defined as pain localized to the pelvis below the umbilicus and usually caused by pelvic organs, as well as pelvic bones, muscles, nerves, joints or blood vessels (1). It can be categorized as acute or chronic. The American College of Obstetrics and Gynecologists defines chronic pelvic pain (CPP) as “pain in the pelvic area that lasts for 6 months or longer and results in functional or psychological disability or requires intervention and treatment” (2,3). CPP can be constant or intermittent. It can be associated with menstruation (dysmenorrhea) or with sexual intercourse (dyspareunia) (4).

According to an extensive review conducted in 2014 the prevalence of noncyclical CPP was reported between

^ ORCID: Salih Yilmaz: https://orcid.org/0000-0002-3473-0525; Nura Fitnat Topbas Selcuki: https://orcid.org/0000-0002-5749-9987; Taner Usta: https://orcid.org/0000-0002-2208-3316.
5.7% and 26.6% (5). CPP is the reason for 1 out of 10 gynecological outpatient visits, indication for 15–40% laparoscopies and 12% hysterectomies in the United States (US) (6,7). CPP has a complex pathophysiology, which has not been completely understood. One of the reasons for this complexity is that frequently no underlying pathology can be found. Furthermore, changes in the central nervous system have been identified in CPP patients, which could explain the disparity between the extent of the pathology observed at laparoscopy and the pain perceived by the patient (8,9). Therefore, management of CPP is complicated.

### Conditions associated with CPP

A variety of conditions can cause CPP. CPP can be visceral, caused by pelvic organs (bladder, colon, uterus, ovaries, rectum, etc.), can be somatic caused by the musculoskeletal system or can be neuropathic generated by the nerves (2). Furthermore, CPP can be associated with psychosocial disorders such as abuse, depressive disorders, anxiety disorders, somatic disorders and substance use disorders (3). Differential diagnosis of CPP is summarized in Table 1.

In this review the focus will be on the gynecological and the retroperitoneal pathologies and their minimal invasive surgical treatment from a gynecological and neuropelveological perspective.

### Minimally invasive surgery

Under the definition of minimally invasive surgery, surgical procedures, which minimize the surgical incisions and thus expedite wound healing time, decrease post-operative pain and risk of infections, is understood (10). From a gynecological perspective, minimal invasive procedures encompass vaginal approaches such as hysteroscopy and laparoscopic approaches such as conventional laparoscopic and robot-assisted laparoscopic surgery. According to the US surgical data between 1998 and 2010, a decrease in abdominal hysterectomies from 65% to 54% and an increase in minimally invasive techniques have been observed (11).

### Vaginal approach: hysteroscopy

Hysteroscopy falls under the category of vaginal techniques

<table>
<thead>
<tr>
<th>Table 1 Differential diagnosis of CPP, possible etiologies according to the scope of this study</th>
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<tbody>
<tr>
<td><strong>Gynecological disorders</strong></td>
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<tr>
<td>Pelvic adhesions</td>
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<td>Endometriosis</td>
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<td>Adenomyosis</td>
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<td>Leiomyoma</td>
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<td>Ovarian remnant syndrome</td>
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<td>Adnexal mass</td>
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<td>Chronic pelvic inflammatory disease</td>
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<td><strong>Vascular disorders</strong></td>
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<td>Pelvic congestion syndrome</td>
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<td>Nutcracker syndrome</td>
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<td><strong>Urologic disorders</strong></td>
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<td>Interstitial cystitis</td>
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<td>Painful bladder syndrome</td>
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<td>Chronic urinary tract infections</td>
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<td>Urethral diverticulum</td>
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<td>Urologic malignities</td>
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<td><strong>Gastrointestinal disorders</strong></td>
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<td>Inflammatory bowel disease</td>
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<td>Celiac disease</td>
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<td>Irritable bowel syndrome</td>
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<td>Diverticulitis</td>
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<td>Hernia</td>
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<td>Colorectal malignities</td>
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<td><strong>Neurologic disorders</strong></td>
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<td>Neural injury</td>
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<td>Nerve entrapment</td>
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<td>Abdominal migraine</td>
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<tr>
<td>Neuralgia</td>
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<tr>
<td>Neuropathic pain</td>
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<tr>
<td>Abdominal epilepsy</td>
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<tr>
<td><strong>Musculoskeletal disorders</strong></td>
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<tr>
<td>Psychosocial disorders</td>
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<tr>
<td>CPP, chronic pelvic pain.</td>
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in the treatment of CPP. Pathologies such as intrauterine adhesions, polyps, some classes of leiomyomas and to a limited extent adenomyosis can be treated with hysteroscopy. It has been reported that in the presence of leiomyomas of classes 0–2, which cannot be visualized by an abdominal approach but still might be the underlying cause of CPP can be diagnosed and treated with hysteroscopy (12).

**Laparoscopic surgery in gynecology**

Since the first description of laparoscopic hysterectomy in 1989, laparoscopic surgery has gained in popularity over the last decades and has replaced laparotomy especially in the treatment of benign gynecological conditions despite longer operation times and longer learning curve (13,14). The reason for this increase in laparoscopic surgery is the quicker return of the patients to their normal activities, shorter hospital stays, and fewer wound or abdominal wall infections (14). Furthermore, due to the small incisions, enlarged visual field and the use of powered surgical tools, laparoscopic surgeries are associated with reduced blood loss and decreased postoperative pain (15-17). Laparoscopic surgery can be performed either with the conventional techniques or with the use of a robotic platform.

**Diagnostic laparoscopy (DL)**

DL provides a total examination of the whole abdominal cavity. According to a study conducted by Howard et al. in 1993, 44% of DLs were performed with an indication of CPP (1). Wiener et al. reported that the primary indication for laparoscopies in UK and the secondary in the US was pelvic pain (18). Back then DL was considered as the gold standard in diagnosis and management of CPP. However, currently with the advance of non-invasive diagnostic and imaging techniques such as 3D ultrasonography, magnetic resonance neurography (MRN) and with a multidisciplinary evaluation, DL has become a second line diagnostic and treatment modality (19). Another challenge with DL arises with the finding of a complicated pathology which is prone to complications. In such situations the surgeons are left with a medicolegal dilemma of taking the risk of causing possible complications and opting for an excision of the pathology perioperatively.

In a retrospective study including 82 CPP patients, in 66% a pathology was identified during DL whereas only 38% received a positive presurgical diagnosis using non-invasive techniques (20). According to a survey conducted by Howard et al. the most common findings in DL were endometriosis and adhesions with a rate of 35% and 24%, respectively (1). Although the findings causing CPP were similar in most of the studies, their percentages differed most probably due to the differences in the patient cohorts (Table 2) (21-25). In addition, approximately in one third of the cases no pathology was detected. However, most of these women stated that going through DL helped them in coping their pain symptoms indicating a psychological involvement associated with laparoscopy (26). Elcombe et al. also observed improvement in pain symptoms following DL even in the absence of a pathology (27).

DL is an invasive procedure and therefore, nowadays it is not routinely performed. It should also be kept in mind that with DL only intraperitoneal pathologies are detectable. Therefore, the presence of possible retroperitoneal pathologies could be missed. Furthermore, in one third of the women with CPP non-gynecological causes should be considered under differential diagnosis before opting for surgery.

**Robot-assisted laparoscopic surgery**

When compared to conventional laparoscopy, robot-assisted laparoscopic instruments allow a wrist-like motion imitating a human hand and therefore even the basic techniques such as suturing can be more easily learned and performed (28). Furthermore, robotic platform enables a higher quality 3D vision of the surgical field when compared to the conventional laparoscopy (29). Thus, a better visualization of smaller pelvic spaces enables an easy access, better dissection and decreased blood loss (30). However, there is inconsistent data regarding the costs of robot-assisted laparoscopy. Some studies have reported a higher cost in the use of robotic platform (31). Whereas others did not find a significant difference between the costs of conventional laparoscopy and robot-assisted laparoscopy (32,33). Robot-assisted laparoscopy can be applied to all surgeries where a conventional laparoscopy is possible. Especially, robotic platform can be advantageous when operating on deep pelvic spaces such as the nerve entrapment operations in the retroperitoneal region (34). Surgeons such as Lambaudie et al. compared the advances in robot-assisted laparoscopy to the technological evolution of conventional laparoscopy 50 years ago (35).

**Surgical interventions in the treatment of CPP**

**Adhesion surgery**

Adhesions are the most frequent pathological findings of...
DL performed due to CPP (21,23,25) (Figure 1). According to a meta-analysis, adhesions are accountable for 57% of CPP cases (36). Previous abdominal surgeries, pelvic infections and inflammation are among the factors causing pelvic adhesions. Preoperative assessment of adhesions can be tricky, because a physical examination and also advanced imaging techniques might not be helpful in identifying intraabdominal adhesions (37).

It is still a topic of debate whether these adhesions cause CPP and whether surgery is the treatment of choice. Nezhat et al. explained that pain could be caused by pull on the parietal peritoneum by the adhesions during bowel peristalsis (38). Furthermore, restrictions on the visceral movement through bowel adhesions could be the underlying mechanism (39). On the other hand, Cheong et al. reported that a correlation between the severity, intensity and duration of pain and the localization or type of adhesions visualized during DL did not exist (40). Furthermore, patient anamnesis especially surgical history differentiating between laparoscopy and laparotomy is an essential part of the evaluation. The risk of adhesion formation is higher following a laparotomy than a laparoscopy (41,42).

Several studies support adhesiolysis as an effective treatment of CPP. In a longitudinal study conducted by Nezhat et al., they evaluated pain levels following laparoscopic adhesiolysis in previously hysterectomized patients without any history of endometriosis with a follow-up period of 5 years. They reported pain relief in 72% of the patients postoperatively at 2–8 weeks, in 64% postoperatively at 6–12 months and in 67% postoperatively at 2–5 years (38). Cheong et al. reported a decrease in visual analogue scales (VAS) evaluating pain and an increase in quality of life scores at 6 months follow-up after adhesiolysis (43). Onders et al. performed adhesiolysis in 45 out of 70 patients who received DL due to CPP. Short-term postoperative evaluation yielded a complete relief of pain and at the 6-month follow-up 71% of the patients were still pain free (44).

Although positive effects of adhesiolysis have been

Table 2 Laparoscopic findings on diagnostic laparoscopy in patients with CPP (21-25)

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Patients (n)</th>
<th>No visible pathology (%)</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drozgyik et al.</td>
<td>1,061 patients with CPP</td>
<td>30</td>
<td>28% Adhesions</td>
</tr>
<tr>
<td>Kang et al.</td>
<td>3,068 patients with CPP</td>
<td>21</td>
<td>19% Endometriosis</td>
</tr>
<tr>
<td>Doyle et al.</td>
<td>189 patients with CPP</td>
<td>35</td>
<td>60% Endometriosis</td>
</tr>
<tr>
<td>Milingos et al.</td>
<td>369 patients with infertility + CPP</td>
<td>18</td>
<td>13% Pelvic congestion</td>
</tr>
<tr>
<td>Behera et al.</td>
<td>124 patients with CPP, previously TAH + BSO</td>
<td>2</td>
<td>38% Adhesions</td>
</tr>
</tbody>
</table>

CPP, chronic pelvic pain; TAH, total abdominal hysterectomy; BSO, bilateral salpingo-oophorectomy.

Figure 1 Adhesions visible at diagnostic laparoscopy. LO, left ovary; U, uterus; LUL, left uterosacral ligament; RUL, right uterosacral ligament; RT, right tube.
reported, the percentage of patients experiencing pain relief varied among studies. In a systematic review, in 18 out of 22 studies representing 92% of the patient population the percentage of pain relief ranged from 56% to 88% (45). A comparison of laparoscopic adhesiolysis with DL at 12-month follow-up in a randomized controlled study yielded no significant differences in VAS scores and quality of life scores of the patients indicating that adhesiolysis had no advantages over DL (46). Due to the randomized design of the study, surgeons were left in a dilemma regarding the efficacy of adhesiolysis. Roman et al. published a critique of this study under the name “Why laparoscopic adhesiolysis should not be the victim of a single randomized clinical trial” where they concluded that the results of this randomized trial were based on a miscalculation of the sample size and statistical power and therefore was insufficient to show the difference between DL and adhesiolysis (47).

There is no evidence supporting the efficacy of agents for adhesion prevention (41,48). Therefore, to prevent adhesion formation meticulous surgical techniques, which minimize tissue trauma while achieving optimal hemostasis and minimizing the risk of infection are important (49). Gomel et al, reported better results in terms of postoperative adhesion formation, following the application of microsurgical techniques (50). In a study conducted by Luciano et al. where 38 patients underwent laparoscopic adhesiolysis due to moderate to severe adhesions and where they received a second round of laparoscopy 4 weeks after the initial surgery, a significant reduction of the extent and severity of adhesions was observed (51). The preferred method of adhesiolysis especially in the presence of filmy adhesions is dissection with cold scissor (Figure 2). The use of bipolar electrosurgery should be minimal. Ultrasonic scalpel can also be applied on dense adhesions with the advantage of less thermal spread. Although experienced surgeons apply adhesiolysis to filmy adhesions and prefer adhesiectomy to treat dense adhesions, these techniques have not yet been systematically tackled in literature. Studies comparing the efficacy of these two techniques are needed.

**Endometriosis surgery**

Endometriosis is one of the most common causes of CPP. The disease has a prevalence of 5–21% among women who are hospitalized for pelvic pain (52). On average diagnosis takes about 7 years and during these 7 years patients who are suffering from severe pain seek a solution from a variety of specialists (53).

Endometriosis cause symptoms depending on the organ involvement. Thus, an ovarian endometrioma does not manifest itself same as deep infiltrating endometriosis (DIE). DIE is more severe and depending on the affected organs can be responsible for dysuria, dyspareunia, cyclic or non-cyclic CPP. CPP affects endometriosis patients’ social lives, they fail to attend school or continue their work (54).

One of the most common findings on DL performed with an indication of CPP has been reported as endometriosis (1,21-23). Management of endometriosis related pain can be medical or surgical. Many medical treatments have been implemented and have been effective in suppressing the disease (55). However, none of them are curative. Surgical options can be conservative such as ablation or excision of endometriosis tissue, drainage, excision or sclerosis of endometriomas and excision of bowel nodules. Radical surgery involving hysterectomy with or without bilateral salpingo-oophorectomy (BSO) is also an option (56). In young women who wish to preserve fertility conservative surgery is commonly performed. However, an estimated 50% recurrence has been reported (57). Furthermore, DIE surgery requires a multidisciplinary team with colorectal surgeons and urologist who are also trained in endometriosis surgery. Therefore, ESHRE Guidelines recommend the referral of women with DIE to specialized endometriosis centers where a team of specialists are involved in the management (58).

In a randomized study, Abbott et al. compared DL with laparoscopic excision of endometriosis and reported an 80% improvement in quality of life and VAS scores at 6th month following endometriosis surgery (59). Cochrane review also reported the benefits of endometriosis surgery over
DL (60). In a multicenter prospective study conducted at 51 certificated endometriosis centers with 4,721 patients, a significant reduction in VAS scores assessing premenstrual pain, menstrual pain and non-cyclic pelvic pain and a significant improvement in quality of life scores at 6th month following laparoscopic excision of deep endometriosis was reported (61).

Minimally invasive surgery, both conventional laparoscopy and robot-assisted laparoscopy, is beneficial in endometriosis-related pain. However, additional postoperative medical treatment such as gonadotropin-releasing hormone (GnRH) analogues, progestins or levonorgestrel intrauterine devices (LNG-IUD) is needed to reduce recurrence and alleviate pain (62).

**Adenomyosis surgery**

Adenomyosis triggers chronic inflammation in the myometrium through diffuse or focal invasion, and this inflammation is responsible for the pain (63). Incidence varies depending on age and ethnicity (64). In 25–65% of hysterectomy specimen adenomyosis was reported histopathologically (65). In the past, the reason for this high histopathological diagnosis following hysterectomy was due to the insufficiency in preoperative diagnosis. However, today ultrasonographic findings of adenomyosis are well described (66). Studies show that adenomyosis can be identified with high sensitivity and specificity using transvaginal ultrasonography (67,68). In addition, magnetic resonance imaging (MRI) can also be used in the preoperative diagnosis (69,70). Although medical treatment such as nonsteroidal anti-inflammatory drugs (NSAIDs), GnRH analogues, LNG-IUD and uterine artery embolization can be used in the treatment, gold standard is hysterectomy (71).

Adenomyosis surgery involves either a complete excision of the disease called adenomyomectomy or a cytoreductive surgery called partial adenomyomectomy (72). Kwack et al. compared 108 laparoscopic and 116 laparotomic adenomyomectomies and observed a significant alleviation in symptoms (73). The authors recommended laparotomic approach in diffuse adenomyosis and laparoscopy in focal adenomyosis.

Differentiation between adenomyotic tissue and the surrounding healthy myometrium issue is not always possible. Therefore, dissection can be difficult (74). For this reason, a standard surgical technique in uterus sparing surgery for patients with a fertility wish does not exist. Several studies have reported the application of uterus sparing surgical techniques in adenomyosis surgery (74-77). Osada et al. reported complete resection of diffuse adenomyosis with laparotomy and showed a significant reduction in pain. Furthermore, during the long-term follow-up, 58% of these patients gave birth to healthy infants (74). Saremi et al. observed a significant relief in dysmenorrhea following adenomyomectomy in 41% of their patients (75). Takeuchi et al. performed laparoscopic adenomyomectomy on 14 patients and reported significant decrease in the VAS scores during the follow-up (77).

Chung et al. performed laparoscopic adenomyomectomy in 25 patients with conventional techniques and in 8 patients with robot-assisted laparoscopy and stated the feasibility of minimally invasive surgical options in uterus sparing surgeries (78). These findings were supported by Chung et al. (79). A study comparing robot-assisted laparoscopic adenomyomectomy with laparoscopic adenomyomectomy reported no significant differences between the two methods (80). Although these studies were not conclusive on the advantages of robot-assisted laparoscopy, the advance mobility of robotic instruments and higher quality of 3D vision is likely to be advantageous in adenomyosis tissue excision and suturing. However, further studies are needed to support these hypotheses.

**Myomectomy**

Whether leiomyomas cause CPP is dependent on their localization, size, number and if they are degenerated or not. The most common symptom of leiomyomas is abnormal uterine bleeding. This abnormal bleeding causes uterine contraction, which causes cyclic pelvic pain (69). In addition, large leiomyomas can compromise neighboring structures resulting in pain.

In comparison to other pathologies leiomyomas rarely cause CPP. Therefore, a thorough examination is recommended to exclude other pathologies (81). However, if a decision is made for myomectomy, conventional laparoscopy or robot-assisted laparoscopy should be the choice of surgical technique (65). In addition, a comparison between laparoscopic myomectomy and myomectomy with mini-laparotomy, also showed the superiority of laparoscopy...
in terms of postoperative analgesia (82).

**Hysterectomy**

Hysterectomy is one of the most common gynecological surgeries performed. Approximately 12% of hysterectomies in the US are performed for CPP (83). It is also the wish of many patients who suffer from CPP due to the notion that uterus is the sole reason for their pain. However, its place in the treatment of CPP is still uncertain. According to a retrospective analysis of 9,622 patients who underwent open or laparoscopic hysterectomies for benign conditions, 40% of the patients were operated with an indication of CPP (84). The high rate reported in this study was due to the exclusion of vaginal hysterectomies, which is the preferred surgical technique in patients with descensus uteri. Hysterectomy is most commonly offered to CPP patients who are in their perimenopausal period or who have no fertility desires.

Before offering a patient hysterectomy as a treatment option, it should be kept in mind that in 40% pain symptoms could persist postoperatively and in 5% pain could worsen (85). Brandsborg et al. reported in 32% of the cases postoperative continuation of CPP during a 15-month follow-up (86). On the other hand, Hillis et al. reported a total recovery in 74%, a decrease in pain symptoms in 21% and persistence of CPP in 5%. They also evaluated CPP in specific subgroups and observed that in the long-term 40% of the patients continued to suffer from CPP (87). In a larger prospective cohort study Hartmann et al. compared postoperatively at 6th and 24th months the quality of life scores and sexual function of CPP patients who presented preoperatively with only CPP or with CPP and depression. According to the results of this study, patients who suffered both from CPP and depression prior to their hysterectomies had poorer results during the 24-month follow-up when compared to patients suffering from either disorder alone or neither. However, all patients including the ones suffering from both disorders showed an improvement in their quality of life scores and their evaluation of sexual function following hysterectomy (88).

In order to decrease the high rates of postoperative persistence of CPP, these patients should be evaluated thoroughly prior to hysterectomy with a multidisciplinary team. Gastrointestinal, genitourinary, musculoskeletal and psychiatric evaluation could reveal other underlying pathologies (49). In addition, a neurolpelveological examination is also necessary to exclude pelvic retroperitoneal pathologies with neural involvement. It has been reported that women who are hysterectomized without a clear preoperative pathological finding benefit less from the surgery (89). However, it is also common in CPP patients that despite thorough preoperative examination an underlying pathology cannot be found as mentioned in DL section.

Following the preoperative evaluation, if hysterectomy is the choice of treatment the operation should be performed with minimal invasive techniques. It is not certain if addition of oophorectomy to the operation is more beneficial on pain (85,90). However, if oophorectomy is also performed, a total excision of ovarian tissue should be aimed in order to avoid ovarian remnant syndrome (ORS) and cause a new pain etiology.

**ORS**

In patients with a history of BSO with or without hysterectomy presenting with CPP, ORS should come to mind. According to Behera et al., 26% of patients who underwent BSO with or without hysterectomy have been diagnosed with ORS (25). ORS occurs following an incomplete excision of ovarian tissue, which results in development of a pelvic mass causing CPP.

Previous abdominal surgeries, pelvic infections, endometriosis, dense adhesions, inflammatory bowel syndrome, ruptured appendicitis, leaving ovarian tissue in pelvis because of an intraoperative complication or inability to ligate ovarian tissue with a safe distance can lead to incomplete removal of ovarian tissue (91). If a patient does not enter surgical menopause following BSO, ORS should be suspected.

Excision of the remnant tissue is the treatment of choice. However, prior to excision iliac vessels and ureters should be dissected and dense bowel adhesions should be removed. Nezhat et al. described a hydro-dissection technique with a laparoscopic approach (92). Following a complete excision of the remnant ovarian tissue, a complete resolution of CPP or significant relief has been reported (93). In order to avoid ORS a sharp dissection instead of a blunt dissection of the adhesions between the ovaries and the adjacent structures has been recommended (91).

**Neurolysis and pelvic denervation procedures**

In order to evaluate retroperitoneal neural involvement in the differential diagnosis of CPP, a comprehensive knowledge on pelvic autonomic and somatic nervous system and their projections on muscles and dermatomes
as a functional unit is required. Without a complete understanding of pelvic neurophysiology, it is impossible to conclude whether a nerve pathology is the underlying etiology of CPP. Also, orthopedic and/or spinal pathologies should be excluded before searching for a pelvic nerve pathology.

The neural evaluation starts with a correct definition of visceral and somatic pain. Visceral component of CPP requires a thorough understanding of the pelvic autonomic innervation. Visceral pain is diffuse, not well localized and it is conducted by the hypogastric plexus. Para-aortic sympathetic trunk forms the superior hypogastric plexus. Neurons descending down bilaterally join the pelvic splanchnic nerves to form the inferior hypogastric plexus. Both sympathetic and parasympathetic fibers of the hypogastric plexus are responsible for conduction of the nociceptive signals from the pelvic organs (94). Due to this autonomic innervation, visceral pain is also associated with symptoms such as malaise, bloating, nausea, vomiting and syncope. On the other hand, somatic pain is conducted by the lumbosacral plexus (L4–5, S1–5) and pathologies affecting the plexus or the somatic nerves origination from the plexus are responsible for well localized pain or loss of sensation at the lower abdominal wall, perineal region and lower extremities (95) (Figure 3).

In addition to a thorough anamnesis neurological examination also involves MRN and/or electromyography (EMG). A thorough surgical history has also utmost importance, because of possible nerve injuries. For instance, lateral trocar entrance areas proximal to the spina iliaca anterior superior are also where the ilioinguinal and iliohypogastric nerves originating from the lumbosacral plexus enter anterior abdominal wall. An injury sustained by the entrance of trocars during laparoscopy, can results in anterior abdominal wall pain. These nerves can also be injured during a herniation repair or by operations where a wide transverse skin incision is required (96). In addition, genitofemoral nerve is located on the psoas muscle and can easily be damaged during abdominal surgery (97) (Figure 4).

Several minimal invasive procedures involving pelvic nerves have been described in literature. Two of them, laparoscopic uterosacral nerve ablation (LUNA) and presacral neurectomy (PSN) are categorized under pelvic denervation. Whereas a newer approach called neuropelveology focuses on nerve sparing techniques also known as neurolysis (95).

**LUNA**

LUNA is a procedure where uterosacral ligaments are transected close to their insertion into the cervix. This leads to the disruption of afferent sensory nerve fibers of the Frankenhauser plexus, which are responsible for pain originating in uterus, cervix and other pelvic structures. Before the introduction of laparoscopy, this procedure was performed by either a vaginal or an abdominal approach (98). Currently, LUNA is performed by laparoscopy using laser or bipolar electrosurgery followed by transection of the ligaments with cold scissors.

When LUNA was first introduced to practice, it was widely accepted. However, as the knowledge of pelvic neural anatomy advanced, the idea of nerve transection to treat pain became absurd. From a neuropelveological perspective
anatomical disruption of nerve fibers does not have a place in pain treatment. This realization was also supported through several studies, which showed that LUNA was ineffective in the treatment of CPP, dysmenorrhea, dyspareunia and did not have a positive effect on quality of life (99,100). Furthermore, in a double blinded study conducted by Johnson et al. on 123 women, LUNA was found to be ineffective on non-menstrual pain, dyspareunia and dyschezia regardless of the presence of endometriosis. The authors concluded that neuroablative surgeries like LUNA could only be successful if all the afferent nerves from all pelvic organs were to be transected. Since such a procedure was unrealistic, the authors pointed out that neuroablative surgery was not suitable for CPP treatment (101).

PSN

PSN is another pelvic denervation procedure where the afferent presacral nerve fibers are transected at the superior hypogastric plexus. When compared to LUNA in patients with primary dysmenorrhea, PSN was reported to be more effective in the long-term treatment (102).

PSN is performed mostly in addition to a surgical procedure to enhance pain treatment. In a study conducted by Nezhat et al. in 75% of the patients with endometriosis who underwent endometriosis surgery with PSN, postoperative pain was significantly reduced (103). However, since this study did not include a control group, it was not conclusive whether the reduction in pain was due to PSN or endometriosis surgery. In a randomized controlled study with 71 moderate to severe endometriosis patients conservative endometriosis surgery and conservative endometriosis surgery with PSN were applied (104). During a 12-month follow-up no significant difference between the groups in terms of dysmenorrhea, CPP and dyspareunia were observed. A slight reduction in the midline component of menstrual pain was reported however this reduction was not statistically significant. Zullo et al. designed a double-blind randomized controlled study with 141 patients with endometriosis who underwent surgery with or without PSN. At 6th and 12th month follow-up examinations significant improvement in dysmenorrhea, dyspareunia and CPP were observed in patients who had received PSN (105).

Due to the localization of the superior hypogastric plexus below the level of the aortic bifurcation between the common iliac vessel at the interiliac triangle, which is surrounded densely by vessels and nerves, this procedure is prone to complications related to injury (106). In addition, complications such as chylous ascites, urinary retention, small bowel obstruction, painless labor, vaginal dryness and sexual dysfunction have also been reported (107). The most common complication following PSN was constipation observed in 74% of the cases (108).

According to literature the effectiveness of PSN in treatment of CPP is still inconclusive. Similar to the reasoning with LUNA, nerve transection should not be a choice of treatment without clarifying the etiology of pain. With the current advances in minimal invasive surgery nerve sparing procedures are more commonly performed. However, PSN could still be used in the treatment of midline pain where other treatment options have failed. More randomized controlled studies with larger cohorts are needed to evaluate PSN effects on treatment of midline pain (109).

Neurolysis

With the introduction of laparoscopic neuronavigation (LANN), first described by Possover et al., the visualization of retroperitoneal area with laparoscopy and the dissection of autonomic and somatic nerves under microscopic view became possible (110). Following this visualization of the lumbosacral plexus, nerve pathologies such as entrapment or direct involvement of the nerve fibers could be identified (94,111).

It has been shown with LANN that endometriosis is responsible for all the pathologies involving nerve fibers in the retroperitoneal area. According to Siquara De Sousa et al. in the presence of retroperitoneal endometriosis a 57% lumbosacral plexus involvement and a 39% sciatic nerve involvement has been reported (112). Possover et al. have shown that in the treatment of neural involvement of endometriosis, resection of endometrial tissue present within the nerve is possible without causing any neural complications (111). Endometriosis can also infiltrate into the sacral nerve roots. Sympathetic fibers are more affected than the somatic fibers, because the hypogastric fascia acts as a barrier against endometriosis infiltration (113). In 40% of patients with DIE and in 72% of patients with hypogastric endometriosis deep lateral pelvic endometriosis has also been observed (114). CPP was also reported as the main symptom and indicator of deep later pelvic endometriosis (114). Possover et al. reported that neurolysis of the sacral nerve roots is sufficient and unchallenging in the treatment of endometriosis involving sacral nerves since endometriosis does not infiltrate into the epineurium (111,113).

The second pathology which can be treated with the neuropelvological approach is the entrapment of a nerve. Entrapment can be caused by endometriosis, vascular
malformations/dilatations, fibrosis and piriformis syndrome where the piriformis muscle fibers entrap the sciatic nerve (94). Previous surgeries, especially pelvic reconstructive surgery have been reported to be responsible for fibrosis in the retroperitoneal area (25,115). Laparoscopy should again be the first line treatment of neural entrapment especially in treating fibrosis following pelvic surgery (116).

Knowledge on neuropelveology enabled surgeons to look for causes of CPP in the retroperitoneal area when DL revealed no findings. A joint evaluation done by a well-trained radiologist and surgeon can lead to a better preoperative diagnosis. Retroperitoneal area, a risky area due to the dense localization of vessels and nerves can be dissected without causing any complications by a surgeon who is trained in anatomy and neuropelveology leading to full recovery with low morbidity (111,114)

Vascular entrapment
Vascular abnormalities can also be the cause of nerve entrapment (Figure 5). However, due to the lack of knowledge on this condition by the clinicians and misdiagnosis of these patients, the actual prevalence is unknown. Patients suffer from severe menstrual pain, an increase in CPP during the day associated with the time a patient spends on her feet and an increase in symptoms during pregnancy.

Its etiology can be explained by dilated or malformed branches of the iliac vessels, most likely originating from the iliac vein, which can entrap the nerves of the sacral plexus against the bony structures of the pelvis resulting in above-mentioned symptoms. Furthermore, this condition can present itself in addition to CPP with sciatica, perineal pain, refractory urinary and defecatory dysfunctions (111).

Patients presenting with these symptoms should be examined both from a gynecological and from a neuropelveological perspective. Standard MRI might not be enough to determine the pathology. A radiologist trained in detecting these vascular malformations are vital for the pre-operative evaluation (117).

Possover et al. reported in a series including 97 patients 3 common localizations of entrapment. According to their study, in 62 patients, after entering the sacral foramen, nerves originating from the S2–4 sacral roots are entrapped between piriformis muscle and hypogastric fascia. In 24 patients pudendal nerve is entrapped at the lesser sciatic notch, and in 11 patients sciatic nerve is entrapped before entering the greater sciatic notch between linea terminalis and dilated vessels (118). In addition, they also reported that pain symptoms were associated with the localization of entrapment.

From a neuropelveological perspective the treatment of vascular entrapment encompasses the entrance of lumbosacral fossa either with laparoscopy or with robot-assisted laparoscopy and coagulation and ligation of the malformed or dilated vessels (34,119). An experienced surgeon familiar with the pelvic anatomy and with a thorough pre-operative evaluation can perform this decompression surgery without any complications (118).

Pelvic congestion syndrome (PCS)
PCS should come to mind as differential diagnosis of CPP especially in women of premenopausal age. An increase in pain during the day and before menstruation and pain following sexual intercourse are associated with PCS. In addition, presence of varicose veins in vulva and lower extremities can hint to the presence of PCS (120). Actual incidence is unknown. Kang et al. reported that in 13% of DL performed for CPP, PCS was the diagnosis (22). DL is not recommended in PCS cases, because the dilated pelvic veins collapse due to the Trendelenburg positioning of the operating table. If PCS is suspected during DL pelvic vessels should be evaluated after the elevation of the patient’s head (121). Venography is the gold standard in diagnosis. If medical treatment is not successful, ligation of varicose veins or hysterectomy with BSO can be performed (122,123). Embolotherapy is also a successful treatment option (124).

Conclusions
Due to the multifactorial etiology of CPP, its diagnosis and management is challenging in clinical practice. CPP can
be caused by gynecological, gastrointestinal, urological, musculoskeletal and psychological conditions. Therefore, a multidisciplinary management and if possible in specialized centers is recommended. Nowadays, with the advances in minimal invasive surgical techniques and with the introduction of new approaches such as neuropelveology more patients receive a successful diagnosis and treatment. Even in complicated operations such as DIE surgeries, both conventional laparoscopy and robot-assisted laparoscopy have replaced laparotomy. As the understanding of pelvic neurophysiology advances nerve sparing surgeries with minimal invasive techniques are replacing neuroablative procedures with better outcomes. Thus, minimal invasive surgery is now the gold standard in surgical treatment of CPP. However, despite of all these advances recurrence and persistence of pain postoperatively should always be kept in mind. Therefore, a multidisciplinary preoperative evaluation is always emphasized for better outcomes. In Table 3, the take-home messages of this review can be seen.

### Table 3 Take-home messages

Due to the multifactorial etiology of CPP, a multidisciplinary evaluation is required.

Neuropelveological approach encompasses a better understanding of pelvic neural anatomy and neurophysiology enhancing management success.

Especially in the presence of previous abdominal operations or infection, adhesions should come to mind as the cause of CPP.

DL should be the last choice in diagnosis and treatment of CPP.

Denervation procedures (LUNA and PSN) should be considered as a last resort treatment option in pain management. Instead the focus should be on finding a pathology.

Retroperitoneal pathologies should also come to mind in differential diagnosis.

A postoperative recurrence or persistence of pain should always be kept in mind.

CPP, chronic pelvic pain; LUNA, laparoscopic uterosacral nerve ablation; PSN, presacral neurectomy.

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