Laparoscopic myomectomy focusing on the myoma pseudocapsule: technical and outcome reports

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BACKGROUND: Our aim was to assess surgical complaints and reproductive outcomes of laparoscopic intracapsular myomectomies by a prospective observational study run in University affiliated hospitals.

METHODS: Between 2005 and 2010, 235 women underwent subserous and intramural laparoscopic myomectomy of fibroids (4–10 cm in diameter) for indications of pelvic pain, menstrual disorders, a large growing myoma or infertility. The main outcome measures were postsurgical parameters, including complications, the need for subsequent surgery or symptomatic relief, resumption of normal life and reproductive outcome.

RESULTS: Pelvic pain occurred in 27%, menorrhagia or metorrhagia in 21%, a large growing myoma in 10% and infertility in 42% of women. Single fibroids occurred in 51.9% of patients while 48.1% had multiple myomas. Of all patients, 58.2% had subserosal and 41.8% had intramural myomas. No laparoscopies were converted to laparotomy. In 3 years, 1.2% of patients had a second laparoscopic myomectomy for recurrent fibroids. The mean total operative laparoscopic time was 84 min (range 25–126 min), with mean blood loss of 118 ± 27.9 ml. By 48 h after surgery, 86.3% were discharged with no major post-operative complications. No late complications, such as bleeding, urinary tract infections or bowel lesions, occurred. Of the women who underwent myomectomy for infertility, 74% finally conceived. At term, 32.9% of patients underwent Caesarean section, 24.8% delivered by vacuum extractor and 42.2% had spontaneous deliveries. No case of uterine rupture occurred.

CONCLUSIONS: Intracapsular subserous and intramural myomectomy saving the fibroid pseudocapsule showed few early and no late surgical complications, enhanced healing by preserving myometrial integrity and allowed a good fertility rate and delivery outcome. In young patients suffering fibroids, laparoscopic intracapsular myomectomy is a potential recommended surgical treatment.

Key words: leiomyoma / uterine fibroids / laparoscopic myomectomy / pseudocapsule / surgical outcomes

Introduction

Uterine myomas are the most frequent tumours of the female genital tract affecting 20–50% of all women, with an increased incidence in the later years of a woman’s reproductive life (Sami Walid and Heaton, 2011). One woman out of two develops a uterine myoma, especially during the reproductive years, and these fibroids are often asymptomatic. Pedunculated, subserous and intramural myomas can be treated by laparoscopic enucleation (Lethaby and Vollenhoven, 2011), but with submucous myomas, there is a well-defined relationship with infertility and fertility outcomes are improved only with excision of submucous leiomyomas. However, the role of intramural and subserous myomas in the genesis of infertility is questionable at best. Intramural and subserous myomectomy has not been shown in
well-designed studies to improve fertility and pregnancy outcomes. In addition, there is a dramatic impact of submucous myomas on expression of HOXA 10 and 11, molecular markers of endometrial receptivity, that is not shared by intramural or subserosal myomas (Rackow and Taylor, 2010). While abdominal myomectomy results in a limited morbidity similar to that of hysterectomy (LaMorte et al., 1993), laparoscopic myomectomy provides clear advantages in medical, social and economic terms, with lower post-operative pain and shorter recovery time (Di Gregorio et al., 2002). Semm and Mettler (1980) published their first findings on laparoscopic myomectomy in 1980. Today, large intramural myomas may be enucleated by this technique (Mettler et al., 2004). Generally, the overall risk of uterine rupture during pregnancy or labour after myomectomy is 2.4/1000 between 29 and 35.5 weeks, but always before 37th week for extensive muscular damage or excessive use of diathermo-coagulation (Frishman and Jurema, 2005). To minimize this risk, it is important to preserve the uterine anatomical and functional integrity during myomectomy, especially in fertile women (Frishman and Jurema, 2005). There is still little documentation regarding most technical aspects of laparoscopic myomectomy. Modern studies of good methodological quality are required in order to accurately define a standard laparoscopic myomectomy technique and to precisely assess advantages and drawbacks of the many variants suggested for each step of the surgical procedure. It is not surprising that the operation procedure relies mainly on the operator’s preferences and may therefore vary greatly between surgeons (Malvasi et al., 2011a,b).

At the beginning of the 20th century, myomectomy was evaluated by several surgeons as an operation performed by relatively atraumatic techniques which involved stretching the myoma from its pseudocapsule to extract the fibroid directly from the surrounding fibromuscular tissue, breaking up the fibrous bridge. Modern laparoscopic intracapsular myomectomy leaving intact the fibrovascular network surrounding the myoma (called the ‘fibroid neurovascular bundle’) (Malvasi et al., 2011a,b), reduces bleeding and/or uterine musculature trauma, and spares the nerve fibres of the pseudocapsule, with a favourable impact on a proper uterine healing and successive functionality (Malvasi et al., 2011a,b).

To evaluate post-surgical parameters, including complications, the need for subsequent surgery or symptomatic relief, reproductive outcomes and resumption of normal life, after laparoscopic intracapsular intramural and subserous myomectomy, the authors performed a prospective observational investigation of a series of patients scheduled for single or multiple intracapsular myomectomy.

**Materials and Methods**

At the Departments of Obstetrics and Gynecology of seven University-affiliated Hospitals, 235 women underwent laparoscopic myomectomy between March 2005 and September 2010. The indications and surgical techniques were evaluated to consider the benefits and limitations of laparoscopic myomectomy. The procedures used in the present study were in accordance with guidelines of the Helsinki Declaration on human experimentation. No specific approval was required by the ethical committee because the laparoscopic approach is the standard surgical procedure for myomectomy at our institutions. The protocol purpose was carefully explained to the patients before they entered the study, and written consent was obtained. Patient selection was based upon the following criteria: pain or pressure symptoms, myomas attributed to infertility or reproductive dysfunction, large and growing myomas and menstrual disorders. For menstrual disorders, we used a criteria similar to that successively established by an international consensus which suggested normal limits for menstrual parameters in the mid-reproductive years: excessive frequency of menses (each 25 days), irregularity of menses (cycle to cycle variation > 20 days), excessive duration of flow (prolonged of 6–8 days) and high volume of monthly blood loss (Fraser et al., 2007).

Vaginal ultrasonography (US), was performed by an expert in transvaginal US to determine the presence of pseudocapsule, as a white ring surrounding the myoma (Fig. 1A) with a peripheral vasoregulation surrounding the myoma, called the ‘ring of fire’ (Fig. 1B; Kurjak et al., 1990), as well as to determine the number, size and location of fibroids, and to exclude patients suspected of having an adenomyosis or adenomyoma (Reinhold et al., 1995). We decided to avoid the use of magnetic resonance in fibroids diagnosis due to problems of costs and time and all removed fibroids were confirmed by final histology.

All selected patients had subserous or intramural fibroids, single or multiple and the dominant fibroid measured between 4 and 10 cm in diameter. Pedunculated, small myomas (< 3 cm in diameter) and submucous leiomyomas were excluded. To best standardize the fibroid location in the uterus, we used the leiomyoma subclassification system of Wamsteker et al. (1993). The system that includes the tertiary classification of

**Figure 1** Transvaginal sagittal sonography showed an intramural myoma. The white arrows highlight the hyperechogenic white pseudocapsule surrounding the fibroid (A). The Echo-Doppler vasoregulation of a myoma shows the peripheral ‘ring of fire’ of the pseudocapsule neurovascular bundle (B).
leiomyomas, categorizes the submucosal group and adds categorizations for intramural, subserosal and transmural lesions. Intracavitary lesions are attached to the endometrium by a narrow stalk and are classified as type 0, whereas types 1 and 2 require a portion of the lesion to be intramural with type 1 being <50% and type 2 at least 50%. Type 3 lesions are totally extracavitary but around the endometrium. Type 4 lesions are intramural leiomyomas that are entirely within the myometrium, with no extension to the endometrial surface or to the serosa. Subserosal leiomyomas (types 5–7) represent the mirror image of the submucosal leiomyomas, with type 5 being at least 50% intramural, type 6 being <50% intramural and type 7 being attached to the serosa by a stalk. Classification of lesions that are transmural would be categorized by their relationship to both the endometrial and the serosal surfaces. The endometrial relationship would be noted first, with the serosal relationship second (e.g. types 2–3). An additional category, type 8, is reserved for leiomyomas that do not relate to the myometrium at all, and would include cervical lesions, those that exist in the round or broad ligaments without direct attachment to the uterus, and other so-called ‘parasitic’ lesions.

Presurgical evaluation included an office hysteroscopy to exclude submucous myomas and other endometrial abnormalities. Preoperative treatment with GnRH analogues was performed in rare cases to avoid distortion of the myoma pseudocapsule, even if GnRH decreases the size of the myoma causing confluent nodular hyaline degeneration and hydropic degeneration necrosis (Friedman et al., 1991; Verkauf, 1992; Mettler et al., 1995; De Falco et al., 2009). In cases with large fibroids and anticipated prolonged surgical times, the surgeon decided whether to operate in two laparoscopic sessions or consider a mini-laparotomy. All patients received a prophylactic antibiotic dosage of Cefazolin 2 g i.v. prior to laparoscopy and an intrauterine manipulator, some supplied with a balloon, to better mobilize the uterus. Laparoscopic myomectomies were performed under general anaesthesia by endotracheal intubation with a standardized four port approach: one port for the laparoscope and three lower quadrant ancillary ports (one suprapubic central 10 mm port and two lateral 5 mm ports). The 10 mm central suprapubic port was often changed to a 15–20 mm port for the introduction of the morcellator at the end of the procedure. Laparoscopic myomectomy by the intracapsular technique was performed without injection of ischemic solution into the myometrium. The visceral peritoneum was incised in the midline longitudinal plane, by monopolar scissors or crochet needle electrode, proceeding in depth into the myometrium to reach the right plane under the myometrium, to detect the myoma pseudocapsule with the fibroid below (Fig. 2A). Once the myoma pseudocapsule was identified, it was well exposed by atraumatic clamp or irrigator cannula, to provide a panoramic laparoscopic view of the pseudocapsule of all subserous-intramural leiomyomas (Fig. 2B). Then the surgeon opened the pseudocapsule by a longitudinal cut, performed by monopolar scissors or Hook electrode at low wattage (30 watt) to expose the myoma surface. Then the fibroid was hooked by a myoma screw or Collins laparoscopic forceps to perform the traction necessary for its gentle enucleation (Fig. 2C), and make enucleation of the myoma difficult (De Falco et al., 2009). Careful patient selection decreases the likelihood of inappropriate laparoscopic myomectomy and avoids conversion to open surgery (Semm, 1991; Campo and Garcea, 1999).
helped by an irrigator cannula being inserted in the space under the myoma pseudocapsule and fibroid. Hemostasis of the small vessels was selectively achieved by a low wattage bipolar clamp or by Hook electrode or monopolar scissors, always at 30 watt, to free the base of the myoma and the connective bridges from the pseudocapsule (Fig. 2D). In such a way, complete minimal traumatic fibroid removal from its pseudocapsule was accomplished with minimal blood loss and pseudocapsule sparing. After that, in case of occasional pseudo-pedunculated myomas, the pedicle was coagulated by bipolar forces or cut by laparoscopic scissors or cut after placement of loops or staples, and no suturing was required. In cases of deep intramural myomas, chromoperturbation was applied via a cervical cannula not only to check tubal patency but also to facilitate the direct recognition of an inadvertently opened uterine cavity. The myometrium was closed in a single (for subserous) or double layer (for intramurals) with 1/0 Vicryl (Polyglactine; Ethicon, USA), including overlapping serosa, with a round CT-1 curved needle, using intra or extracorporeal knots. In subserosal myomectomies (types 5 and 6), the edges of the uterine defect were approximated with introflexion U-inverted stitches (myometrium/serosa-serosa/myometrium direction) with intra myometrial knot, at 1 cm increments from the edge of the incision (as a ‘baseball-type’ suture). The closure was according to the surgeon’s choice, interrupted closure or traditional unidirectional running suture, started at the end of hysterotomy. Deep intramural fibroids (types 2–5 and 3) required a two-layer myometrial closure with introflecting sutures, always by a ‘baseball-type’ suture. If the uterine cavity was accidentally opened during fibroid enucleation, 2–3 deep myometrial single or continuous sutures were applied on the uterine cavity edges. After hysterorrhaphy, fibroids were morcellated with a reusable Rotocut GI morcellator (Karl Storz GmbH & Co. KG, Germany) or by a Gynecare Morcellex tissue morcellator (Ethicon, Inc., Somerville, NJ, USA).

The post-surgical parameters, including complications, the need for subsequent surgery or symptomatic relief, reproductive outcomes and resumption of normal life were all evaluated post-operatively. All parameters collected during surgery and hospitalization were recorded and reported in tables by the surgeons involved in the study. Patients were followed up 12–60 months after surgical treatment using gynaecologic and ultrasonographic examinations, and an interview to determine: (i) complications—immediate or late, (ii) the need for additional or subsequent surgery, (iii) relief of symptoms, (iv) fertility outcome and (v) resumption of normal life. The clinical and instrumental follow-up of patients who requested myomectomy was directed to check and verify the symptoms which they referred to before laparoscopic myomectomy, i.e. the pelvic pain and menstrual disorders investigated in an interview during a gynaecologic visit at admission were questioned at postsurgical follow-up, and the patients’ answers were collected by clinicians. All the data of surgical parameters and follow-up obtained from recorded patient files were estimated and analysed by an independent reviewer.

Summary statistics on the operated patients are presented as frequencies for categorical variables and mean ± standard deviation for continuous variables. To analyse data, we used Student’s t-test for normally distributed variables, χ² test for categorical variables and Mann–Whitney test for non-normal variables. Statistical calculations were performed with MedCalc software, version 11.4.1.0. A P-value <0.05 was considered to be statistically significant.

### Results

The mean age of our population was 36.5 ± 4.3 years (range 28–43 years), mean BMI was 23.9 ± 1.9 and mean parity was 1.1 ± 0.4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall n (%)</th>
<th>Single myomas n (%)</th>
<th>Multiple myomas n (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvic pain, n</td>
<td>63 (26.8)</td>
<td>34 (27.6)</td>
<td>29 (25.9)</td>
<td>0.3730</td>
</tr>
<tr>
<td>Meno-metorrhagia, n</td>
<td>49 (20.9)</td>
<td>26 (21.1)</td>
<td>23 (20.5)</td>
<td>0.5445</td>
</tr>
<tr>
<td>Growing and enlarged myomas, n</td>
<td>24 (10.2)</td>
<td>23 (18.7)</td>
<td>21 (18.8)</td>
<td>0.6698</td>
</tr>
<tr>
<td>Infertility, n</td>
<td>99 (42.1)</td>
<td>48 (39.0)</td>
<td>51 (45.5)</td>
<td>0.6698</td>
</tr>
</tbody>
</table>

<sup>*Mean ± SD.</sup>
of 5–6 cm, as measured by ultrasound. The largest myoma size in multiple myomectomy group was 7 cm of mean diameter. The primary preoperative indications are shown in Table II, and included pelvic pain in 27%, menorrhagia or metrorrhagia in 21%, a large growing myoma in 10% and infertility in 42% (Table II).

There were seven women (2.9%) pre-treated with 3.75 mg leuprolide acetate for 3 months prior to surgery to reduce either excessive duration of flow or the high volume of monthly blood loss before surgery. Intracapsular myoma enucleation was performed by a myoma drill or screw: a monopolar Hook electrode or scissors were used to cut the connective bridges of the pseudocapsule from the surrounding myometrium in 109 women (46.3%). Bipolar clamps were used in the remaining 126 patients (53.6%), without differences in their use for gentle hemostasis of small vessels pseudocapsule. The uterine cavity was entered, during myomectomy, in eight women with a single fibroid (6.5%) and in 14 patients with multiple fibroids (12.3%). Surgeons avoided using any anti-adhesive barrier method after completion of the myomectomy, since they had another surgical trial in course. At the end of the procedure, a catheter was placed for 24 h in the pelvis for postsurgical drainage and bleeding measurement for study in 67 women (28.5%). All laparoscopies were successful without conversion to laparotomy. The mean total operative laparoscopic time was 84 min (range 25–126 min). Mean blood loss was, on average, 118 ± 27.9 ml.

There were with no major post-operative complications. One patient (0.4%) had hematoma formation within the abdominal wall, resolved immediately by epigastric artery stitching. No late complications, such as bleeding, urinary tract infections or bowel lesions occurred. There were 17 women (7.3%) who required therapeutic antibiotics for post-operative fever. No patient required a blood transfusion. Postoperatively, 126 women required analgesic administration for the first 24 h (53.6%), and 203 women were discharged by 48 h after surgery (86.3%), with a range of 2–4 days. Of 113 with multiple myomas, 98 required multiple myomectomy: two were removed in 39 women (16.5%), three in 27 (11.4%), four in 20 (8.5%) and more than four in 12 patients (5.1%). Within 3 years of follow-up, a second laparoscopic myomectomy was suggested for recurrent fibroids in 3 of the 235 patients who underwent primary laparoscopic myomectomy (1.2%). There were 136 nulliparous women who had around one

Of the women who underwent myomectomy for infertility, the median size of fibroid was 7 ± 1.6 cm and 74% conceived. There were 97 who became pregnant by 10–24 months after myomectomy (it was recommended to avoid pregnancy for 6 months after surgery) and delivered at term: 31 of these had suffered of pain (31.9%), 19 menstrual disorders (19.5%) and 47 infertility (48.6%). An analysis of the data showed the following deliveries: 32 patients underwent a Caesarean section on demand (32.9%), 24 were by operative vaginal delivery (OVD; 24.8%), and 41 were by spontaneous delivery (42.2%). No case of uterine rupture occurred in this series. Of Caesarean sections, 9 of these had suffered pain (28.2%), 7 menstrual disorders (21.8%) and 16 infertility (50%). Of those with OVD, 8 had suffered pain (33.3%), 6 had menstrual disorders (25%) and 10 had been infertile (41.7%). Of spontaneous delivery group, 14 had suffered pain (34.1%), 6 had menstrual disorders (14.6%) and 21 had been infertile (51.3%). Stratifying patients’ data, by number of myomas and location for type, we noted of 32 patients delivered by cesarean section (CS), 20 had multiple myomas (62.5%) and 12 had a singular fibroid (37.5%): 22 had myomas types 2–5 of 7 ± 1.3 cm of diameter (68.7%), 7 women had a myoma type 3 (totally extravascular but around the endometrium), of 9 ± 1.8 cm of diameter (21.8%) and 3 were type 4 (intramural leiomyomas that are entirely within the myometrium, with no extension to the endometrial surface or to the serosa) of 8 ± 1.5 cm of diameter (9.5%). Of 24 women delivered by OVD, all by vacuum extractor, 15 had multiple myomas (62.5%) and 9 had single fibroids (37.5%): 12 had type 4 myomas of 7 ± 1.4 cm of diameter (50%), 9 women had type 5 myomas (being at least 50% intramural) of 8 ± 1.7 cm of diameter (37.5%), and 3 women had type 6 myomas (being <50% intramural) of 6 ± 1.2 cm of diameter (12.5%). Of 41 patients delivered by spontaneous delivery, 28 had multiple fibroids (68.2%) and 13 had a single myoma (31.8%): 27 had myomas type 5 myomas (being at least 50% intramural) of 6 ± 1.2 cm of diameter (65.8%), and 14 women had type 6 myomas of 5 ± 1.5 cm of diameter (34.2%). All data are summarized in Table III. Neonatal outcomes included 47% female and 53% male births. The mean gestational age was 40 ± 0.9 weeks, mean Apgar scores were 9.13 ± 0.8 at 1 min and 9.73 ± 0.2 at 5 min, and neonatal weight was 3250 ± 350 g. In long-term follow-ups, only 2 of the 235 women (0.85%) subsequently required hysterectomy for persistent or recurrent complaints associated with abnormal bleeding or pelvic pain.

### Table III  Data of 97 pregnancies after myomectomy, delivered by Caesarean section (CS), OVD or VD.

<table>
<thead>
<tr>
<th>No. of patient for type of delivery</th>
<th>No. of multiple myomas for patients</th>
<th>No. of single fibroid for patients</th>
<th>Type of fibroid</th>
<th>No. of women</th>
<th>Myoma diameter in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>32/CS</td>
<td>20</td>
<td>12</td>
<td>2–5</td>
<td>22</td>
<td>7 ± 1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>7</td>
<td>9 ± 1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
<td>8 ± 1.5</td>
</tr>
<tr>
<td>24/OVD</td>
<td>15</td>
<td>9</td>
<td>4</td>
<td>12</td>
<td>7 ± 1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>9</td>
<td>8 ± 1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>3</td>
<td>6 ± 1.2</td>
</tr>
<tr>
<td>41/VD</td>
<td>28</td>
<td>13</td>
<td>5</td>
<td>27</td>
<td>6 ± 1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>14</td>
<td>5 ± 1.5</td>
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</table>
Discussion

This large prospective series with up to 5 years of follow-up confirms that laparoscopic intramural and subserous intracapsular myomectomy provides excellent surgical and pregnancy outcomes when patient selection is appropriate, there is no other cause for infertility and intracapsular myomectomy is performed (Dubuisson et al., 2001). Based on our data and results from other another large series (Seracchioli et al., 2000; Kubinova et al., 2011), there is increasing evidence that conception and pregnancy outcomes are more favourable with laparoscopic myomectomy than after laparotomic myomectomy. One study found that the time to conception was significantly shorter following laparoscopic myomectomy compared with abdominal myomectomy, although over time, the overall pregnancy rates were similar between the two groups (Soriano et al., 2003). Numerous investigations have shown that pregnancy rates range from 33.3 to 64% within one year of laparoscopic myomectomy (Mais et al., 1996; Seracchioli et al., 2000; Dubuisson et al., 2001; Maizoni et al., 2003; Hackethal et al., 2011). There is no general agreement in the published reports over the best surgical approach to myomectomy in patients with infertility, but our results provide data in favour of laparoscopic intracapsular myomectomy.

Scientific information concerning the vascular supply of fibroids is not abundant and to some extent is controversial, so that some gynaecologists dispute the existence of a pseudocapsule (Frishman and Jurema, 2005; Hackethal et al., 2011; Kubinova et al., 2011; Mattei et al., 2011) or poorly and scantily describe the presence of a capsule surrounding fibroids (Mais et al., 1996). Myomectomy is largely and generally described as the following: a longitudinal vertical monopolar incision in the most prominent part of the fibroid, a myoma screw inserted into the myoma, the fibroid enucleated using constant traction combining adequate traction with a tenaculum forceps with counter-traction with a grasper and monopolar coagulation needle or scissors or a bipolar clamp for blunt dissection, and the myometrium suture made in two or three layers depending on the uterine wound. But being convinced of the existence of the pseudocapsule, we reviewed the myoma pseudocapsule and its structure (Tinelli et al., 2009) and reported our first positive surgical experience comparing removal of single versus multiple intracapsular fibroids (Tinelli et al., 2010). The presence of a pseudocapsule is further supported by vascular corrosion casting studies that clearly demonstrate a peripheral vascular pattern surrounding the relatively avascular myoma (Walocha et al., 2003).

Generally, a correct myomectomy must aim to preserve the integrity of the tissue of the extracellular matrix, either in laparoscopy or in laparotomy, as this ensures the three-dimensional organization of the myometrium after myomectomy (Frishman and Jurema, 2005). This is especially important in a young woman who desires fertility. In recent years, laparoscopic myomectomy has been considered an alternative to laparotomy with numerous advantages including short hospital stays, less need for analgesia, lower intraoperative blood loss and a good outcome in subsequent pregnancy (Soriano et al., 2003). Even if uterine rupture after myomectomy during pregnancy, labour or delivery may occur, the risk is low. In the present study, many women delivered spontaneously (42.2%) after myomectomy, without uterine rupture; of these, 68.2% of patients had multiple fibroids while 31.8% had single myoma, with myomas of type 5 of 6 ± 1.2 cm in diameter for the majority and myomas of type 6 of 5 ± 1.5 cm in diameter for one third of patients. OVD was requested in 24.8% of patients, mostly for women with multiple myomas (62.5%) for the following causes: prolonged second stage of labour, exhaustion of the patient, suspicion of immediate or potential fetal compromise and shortening of the second stage of labour. Women delivered by Cae-sarean section received the operation on their request or due to uncertainty of clinicians; 62.5% had multiple myomas, with overall fibroid diameters of by 7 ± 1.3–9 ± 1.8 cm.

At present, there is no consensus about the factors that increase the risk of uterine rupture after laparoscopic myomectomy, and uterine dehiscences are not limited to laparoscopic myomectomies and they have been reported following abdominal myomectomies as well (Frishman and Jurema, 2005). Operative techniques, instruments, and energy sources differ from those used during laparotomy, and any of these could affect myometrial healing. Failure to adequately suture myometrial defects, lack of hemostasis with subsequent hematoma formation or excessive use of monopolar or bipolar electrocoagulation with devascularization of the myometrium have all been postulated to interfere with myometrial wound healing and increase the risk of rupture (Hurst et al., 2005). Case reports of uterine rupture after laparoscopic myomectomy suggest that the quality of the uterine closure may be suboptimal. Additionally, excessive utilization of high wattage electrosurgery may damage the myometrium (Frishman and Jurema, 2005). When hemostasis is not well established during surgery, a hematoma may develop (Hurst et al., 2005), but extensive and excessive use of high wattage electrosurgery may damage the myometrium (Frishman and Jurema, 2005). Parker et al. (2007) recently reviewed 19 cases of uterine rupture after laparoscopic myomectomy. The removed myomas ranged in size from 1 to 11 cm (mean, 4.5 cm). Only three cases involved multilayered closure of uterine defects, and electrosurgery was used in all but two cases of uterine rupture. No other plausible contributing factors were found. It seems reasonable then for surgeons to adhere to techniques developed for abdominal myomectomy, including limited use of extensive and uncontrolled high wattage electrosurgery (>30 watt) and adequate closure of the hysterotomy.

Finally, we postulate that poor individual wound healing characteristics and altered neurovascular peptide distribution in myoma pseudocapsule could predispose to uterine rupture (Parker et al., 2010). The presence of neuropeptides substance P and vasoactive intestinal peptide, two important neuropeptides, was evaluated in the pseudocapsule of uterine fibroids in a recent study (Malvasi et al., 2011a) and these neuropeptides are present in the specimens of fibroid pseudocapsule, as well as in the prostate neurovascular bundle (Mettler et al., 2011) and in the normal myometrium of the non-pregnant uterus. Since these neuropeptides may affect healing and myometrial function in subsequent pregnancy, the pseudocapsule neurovascular bundle should be protected (Mettler et al., 2011), avoiding destructive proceedings, such as extensive diathermocoagulation. Based on these assumptions and on scar physiology, intracapsular fibroid excision should enhance normal healing of the uterine scar, sparing likely neurotransmitters and would facilitate normal functioning of the myometrium. Thus, we propose that intracapsular myomectomy should always be performed in such a way as to maximize the potential for future fertility and to minimize the risk of uterine rupture during pregnancy and labour (Malvasi et al., 2011a,b).
Moreover, the vascular capsule surrounding the myoma contains a group of vessels which appear as a ‘ring of fire’ (Fig. 1B), as identified by colour Doppler ultrasound (Tinelli et al., 2011). These vessels were studied by a preliminary three-dimensional mathematical model (Malvasi et al., 2011a,b), which showed an increase vascular tortuosity, disarray, an abnormal branching and the presence of ‘cul-de-sac’ vessels. All of these features are similar to features of malignant neoplastic tissue vessels, present in malignant tumours, which could be linked either to rare but possible leiomyoma necrosis, expulsion or degeneration or directly to smooth muscle cell deregulation by angiogenic growth factors. It was not possible in this study to clarify how the pseudocapsule vascular network could be produced, and more research is needed to determine the role of the myoma pseudcapsule neurovascular bundle on the formation, growth and pathophysiological consequences of fibroids, including pain, infertility and reproductive outcomes (Malvasi et al., 2011a,b). Some of these pseudocapsule vessels, moreover, join at the base of the myoma creating a little foot which often bleeds during an incorrect extra-capsular myomectomy, and a careful low energy selective coagulation may be needed to obtain an adequate hemostasis during surgery and to favour myometrial healing and restoration of reproductive potential after myomectomy.

In discussions on consequences of laparoscopic myomectomy on patients, it was stated that adhesion formations are a significant problem after myomectomy, and are associated with a high risk of de novo adhesion formation, and may decrease fertility (Kubinova et al., 2011). Our surgical method already showed a decreased adhesion formation after intracapsular laparoscopic and abdominal myomectomy (6–8 cm), with or without an anti-adhesion barrier. When an adhesion barrier was not used, there was a higher rate of adhesions in laparotomy (28.1%) compared with laparoscopy (22.6%). Filmy and organized adhesions were predominant with an adhesion barrier, and cohesive adhesions were more common without an adhesion barrier (Tinelli et al., 2011). Basing on our data, an adhesion barrier should be always used after laparoscopic intracapsular myomectomy in women desiring pregnancy (Tinelli et al., 2011).

One group recently proposed a method of laparoscopic intracapsular myomectomy for fibroids of 6–18 cm by vasopressin injection followed by loop ligation of the pseudocapsule in 105 women. In their opinion, vasopressin reduced bleeding and better exposed the pseudocapsule. Moreover, they hypothesized that loop ligation of the pseudocapsule provided good hemostasis, allowed the adjacent myometrium and the pseudocapsule to be preserved, and caused the uterine defect to become more superficial, therefore the suturing was easier (Zhao et al., 2010). Analysing literature on ischemic solutions to inject into myometrium, studies have shown that vasopressin decreases blood loss at the time of myomectomy by laparotomy compared with a placebo or a tourniquet. On the other hand, other studies found no difference between the use of vasopressin or a tourniquet at myomectomy performed by laparotomy. In clinical practice, probably either technique will decrease blood loss compared with no intervention, so that the greater magnification afforded by the laparoscope may allow for more precise treatment of blood vessels. In addition, the pneumoperitoneum by CO2 associated with laparoscopy may tamponade small vessels and, cumulatively, result in less blood loss (Frishman and Jurema, 2005). Furthermore, vasopressin injection has been reported to cause pulmonary oedema and, with intravenous injection, even death, while loop ligation may ultimately compromise uterine function and may reduce fertility or increase complications during pregnancy. In our experience the use of vasopressin is not useful and it is likely that the suturing technique is of secondary importance when an intracapsular myomectomy is well performed.

The problem of stitches has never been well approached in myomectomy due to the lack of well stated scientific rationale. As showed in many papers (Tinelli et al., 2009, 2010, 2011; Malvasi et al., 2011a,b), the myoma pseudcapsule is a fibro neurovascular structure, a neurovascular bundle, probably created by the uterus to cope with the development and growth of the fibroid; when the surgeon gently removes the myoma through the pseudcapsule, he/she preserves the muscle surrounding myoma, returning it to normality as a healthy uterine tissue. The same thing happens in the lower uterine segment during pregnancy: after delivery, it disappears. For these reasons, the hysterorraphy after intracapsular myomectomy, in our opinion, needs to be closed by simply introflecting muscle edges, approached in one or two layers. The various described sutures in several layers have no reason to be used, since more foreign body suture materials produces inflammatory reactions, based on submesothelial fibrosis, strengthened by regenerative mesothelial hyperplasia (Malvasi et al., 2009). In such way, after intracapsular fibroid removal, which spares neurovascular fibres and neuropeptides, the uterine muscle is healthy and not traumatized, ready for proper healing. As indicated in our investigation, if the myoma is enucleated entirely through the fibrovascular capsule opening, using traction on the surrounding myometrium and a gentle selective low energy hemostasis on pseudcapsule vessels, the myometrial bed collapses without excessive bleeding once the myoma is removed. This can be demonstrated by the absence of post-myomectomy hematomas after intracapsular myomectomy, which can be assessed by ultrasonographic evaluation of the myomectomy site in the post-operative interval (Seiner et al., 1999).

Regarding the route of post-myomectomy delivery, vaginal delivery (VD) is generally safe following laparoscopic myomectomy (Malzioni et al., 2003; Hackethal et al., 2011), and compared with uterine artery embolization, the risk of preterm delivery and malpresentations is low (Goldberg et al., 2004). In our series, VD was safely achieved in 67% of our patients.

Comparing surgery with other fibroid treatments, laparoscopic intracapsular myomectomy provides other advantages compared with uterine artery embolization. Other possible problems of myoma embolization result from necrosis of the fibroid (Stubner et al., 2004; Stowell, 2011), which can lead to a prolonged in-patient stays with high-dose analgesia, ovarian failure, infertility or endometrial atrophy. Due to lack of histopathology after uterine artery embolization, there is a risk of undiagnosed malignancy. This is a concern, as the rate of sarcoma is 0.5% in women with suspected fibroids. Furthermore, there is no long-term follow-up of the consequences of uterine artery embolization. Recently, magnetic resonance guided focused ultrasound surgery has been proposed as a new option (Stewart et al., 2007; Bouwsma et al., 2011); this method causes heat damage to the relatively a vascular central aspect of the myoma, and should not alter the vascular pseudcapsule. So far however, the short- and long-term results are not very convincing (Bouwsma et al., 2011). Thus, laparoscopic intracapsular myomectomy provides clear advantages over embolization and ultrasound ablation.
Conclusion

A considerable advantage of intracapsular laparoscopic myomectomy is the reproducibility of its application for all laparoscopic myomectomies, as a safe, feasible and minimally invasive technique. Intracapsular myomectomy enhances myometrium integrity peripheral to the fibroid site, by preserving the neurovascular bundle and neurotransmitters surrounding fibroids, for uterine healing and myometrium restoration after surgery. Moreover, allowing correct myometrial healing, intracapsular myomectomy should preserve reproductive outcomes and normal labour and delivery and permit less bleeding, better neurovascular bundle sparing for scar quality and reductions in post-operative adhesions. Increasing knowledge of the pseudocapsule angiogenesis and neurovascular fibres could play an important role in understanding the origin and recurrence of, and correct treatments for, uterine leiomyomas. Therefore this study suggests the need for further investigations on the anatomical and neuropolatholic basis of the fibroid pseudocapsule.

Authors’ roles


Conflict of interest

The authors certify that there is no actual or potential conflict of interest in relation to this article and they reveal any financial interests or connections, direct or indirect or other situations that might raise the question of bias in the work reported or the conclusions, implications or opinions stated, including pertinent commercial or other sources of funding for the individual author(s) or for the associated department(s) or organization(s), personal relationships or direct academic competition.

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