HHS Public Access

Author manuscript

Am J Obstet Gynecol. Author manuscript; available in PMC 2015 June 05.

Published in final edited form as:

Am J Obstet Gynecol. 2015 June ; 212(6): 717–724. doi:10.1016/j.ajog.2015.01.012.

A critical assessment of morcellation and its impact on gynecologic surgery and the limitations of the existing literature

Fong W. Liu, MD, MPH, **Valerie B. Galvan-Turner, MD**, **Krista S. Pfaendler, MD**, **Teresa C. Longoria, MD**, and **Robert E. Bristow, MD, MBA**

Division of Gynecologic Oncology, Department of Obstetrics and Gynecology, University of California, Irvine Medical Center, Orange, CA.

Abstract

Uterine sarcomas are rare uterine malignancies that are difficult to diagnose preoperatively. Because of cases of disseminated sarcoma after laparoscopic hysterectomy, the role of power morcellators in gynecologic surgery has been questioned. Morcellation is an integral part of making laparoscopic surgery possible for the removal of large uterine leiomyomata, and the development of power morcellation has increased efficiency during these procedures. Minimally invasive surgery has demonstrated benefits that include improved pain control, decreased infection risk, and faster surgical recovery and return to work. In this review, we examine the risk of incidental sarcoma at the time of surgery, the quality of the data, the accuracy of clinical and radiologic predictors of uterine sarcoma, and the impact of morcellation on the prognosis of uterine sarcoma.

Keywords

minimally invasive surgery; morcellation; uterine sarcoma

The role of power morcellation in gynecologic surgery recently has come under intense scrutiny after a highly publicized case of dissemination of unexpected uterine leiomyosarcoma. Morcellators were introduced initially in 1973 as a hand-activated device for laparoscopic tissue removal. The first electromechanical morcellator was made available by Steiner in 1993.[1] As minimally invasive surgical techniques evolved, morcellation became a mainstay of gynecologic surgery. However, the risk of spreading malignant tissues must be balanced deliberately with the benefits of minimally invasive surgery. The purpose of this review was to provide an overview of the current literature in incidental uterine sarcomas, the accuracy of clinical and radiologic predictors of uterine malignancy, and a brief review of the impact of morcellation and future guidelines on the use of mechanical morcellators in gynecologic surgery.

Corresponding author: Fong W. Liu, MD, MPH. fongl1@uci.edu.

The authors report no conflict of interest.

Incidence of sarcoma unsuspected at hysterectomy

Uterine sarcomas are rare, comprising <1% of all gynecologic malignancies.[2] This subgroup of uterine malignancies carries a poor prognosis for those affected, even in early-stage disease (Table 1).[3–7] In the United States, of the estimated 52,630 new cases of uterine cancer diagnosed annually, approximately 1600will be uterine sarcomas.[8] The major challenge with triaging patients to the appropriate surgery is differentiating uterine sarcomas from benign uterine fibroid tumors. Using various imaging techniques, endometrial sampling, obtaining a detailed patient history, and performing a thorough physical examination have been the mainstay of preoperative evaluation for patients with uterine masses. Although these techniques provide adequate evaluation for uterine epithelial cancers, each has limitations and none can exclude the possibility of nonepithelial malignancies.

There are varying reports in the literature on the incidence of unsuspected uterine sarcoma diagnosed on final pathologic evaluation after hysterectomy. Additionally, these studies are retrospective, which further limits the quality of the data. In the special report on power morcellation and occult malignancy in gynecologic surgery issued by the American Congress of Obstetrics and Gynecology (ACOG), it is estimated that 1 in 500 women will have a postoperative diagnosis of stromal sarcoma and leiomyosarcoma.[9] As part of the safety warning issued by the US Food and Drug Administration (FDA) on power morcellation, a comprehensive literature review of studies that reported unsuspected uterine sarcomas and leiomyosarcomas in patients who underwent hysterectomy or myomectomy for presumed benign fibroid tumors was performed. Among this population, the risks of occult sarcoma and leiomyosarcoma were reported to be 1 in 352 and 1 in 458, respectively.[10]

Quality of the data

Further review of the studies used for the FDA's report confirms low-quality evidence from retrospective reviews. Moreover, many of the studies were done at large referral centers on high-risk patients, possibly falsely elevating the risk of uterine sarcomas in these study groups. Of the 9 studies that were included in the FDA quantitative assessment, 5 studies were conducted in the United States (Table 2).[11–15] All the studies were qualitative in nature, providing level 3 evidence[16] on the risk of uterine sarcoma at the time of hysterectomy. The largest study included 1429 patients who were 36–62 years old with abnormal uterine bleeding or abdominal pain with a pelvic mass of sufficient size or character to warrant surgical exploration. In that study, they reported 7 cases of leiomyosarcoma (0.5%).[11] Review of the study criteria shows that there was no standard preoperative evaluation among these patients who were treated between 1983 and 1988. The study was based out of a tertiary care center with a self-referred indigent population. Two additional US studies that were reviewed by the FDA report rates of uterine sarcoma of 0.18–0.23% and leiomyosarcoma of 0.08–0.09% in high-risk patients with inconsistent preoperative work-up.[12,14] Notably, of the studies that were reviewed by the FDA, multiple surgical and morcellation techniques were used to treat these patients.

Variable preoperative evaluation and lack of age and risk factor stratification among these retrospective studies ultimately lend uncertain relevance to these published data. With an annual reported incidence of 0.64 per 100,000 women, the applicability is further complicated by the rarity of these malignancies.[17] There are limited data on the prevalence of sarcoma in morcellated specimens and even fewer cases and studies on the incidence of disseminated disease in patients who underwent minimally invasive surgical techniques with the use of power morcellation.[14,18–22] To fully evaluate the effect of power morcellation on disease-free and overall survival in these cases, prospective studies or randomized studies are necessary; however, no such study is possible due to obvious ethical conflicts. Furthermore, the rarity of these cancers requires that data be collected over a long period of time to accrue the necessary numbers to provide sufficient statistical power to detect differences in outcome. Use of epidemiologic modeling systems may be needed to better understand the impact of morcellation in these cases. Without reliable data, any recommendation on the safety of power morcellation is premature, given the known benefits of minimally invasive surgery on patient recovery and quality of life.

Accuracy of clinical and radiographic predictors of malignancy

Historically, clinicians have been challenged by the difficult task of identifying sarcomas before surgery. The accuracy of clinical and radiographic predictors of malignancy varies widely depending on the type of uterine cancer, endometrial vs mesenchymal. The diagnosis of endometrial cancer is made reliably based on histologic and radiologic evaluation. Endometrial biopsy has high sensitivity for a diagnosis of endometrial carcinoma[23,24]; however, very few studies have reported its sensitivity in diagnosis of mesenchymal tumors and are limited to small single-institution reports.[11,25] Because of the distribution of sarcomas within the myometrium, the reported sensitivities of 33–67%are not surprising.

No clear clinical features have distinguished benign uterine neoplasms reliably from malignant growths. Rapidly enlarging uterine size traditionally has been taught as a characteristic of malignant tumors[26]; however, this has not been supported in the contemporary literature.[12,27–29] Parker et al[12] reported on a cohort of 1332 women who underwent hysterectomy or myomectomy; 371 women had rapid tumor growth as their surgical indication, with only 1 case of leiomyosarcoma among this group. A literature review of 26 studies found that a history of rapid uterine enlargement was documented in only 15 of 580 patients (2.6%) with uterine sarcoma. In a more recent review, Leung et al[30] reported only 2 cases of leiomyosarcoma among 155 patients (1.3%) with a “rapidly growing uterus” at the time of hysterectomy. Furthermore, rapid tumor growth of up to 138% of fibroid tumor volume has been demonstrated by benign leiomyomata.[29]

Black race has been associated with a 2-fold increased risk of carcinosarcoma and leiomyosarcoma[31]; however, black women have a 2- to 3-fold increased baseline risk of uterine leiomyomas.[32,33] Increasing age and postmenopausal status are also nonspecific risk factors for uterine sarcomas. Because fibroid tumors are hormone responsive, any growing uterine mass in a postmenopausal patient should be treated as malignancy until proved otherwise. Tamoxifen use for >5 years has also been associated with an increased risk for uterine sarcoma.[34,35] No genetic mutations or polymorphisms have been connected to

uterine sarcomas; however, childhood retinoblastoma and hereditary leiomyomatosis and renal cell carcinoma syndrome have been associated with sarcomas of the uterus.[36–38]

Imaging modalities have emerged as crucial methods in the evaluation, surveillance, and surgical planning of many gynecologic malignancies and neoplasms. Radiologic studies, however, have limited utility in the diagnosis of uterine malignancy. Imaging cannot reliably differentiate malignant from benign causes, and the low sensitivity and specificity of radiologic studies has made triage of uterine masses to the appropriate surgical procedure difficult. Table 3 provides a summary of the utility of imaging modalities in the diagnosis of uterine sarcomas and their respective measurements of interest. All the studies are based on limited case series.

Ultrasound scanning is often the first-line imaging modality for evaluating patients with pelvic disease because of its sensitivity, accessibility, and relative low cost of services. In cases of suspected endometrial malignancy, an endometrial thickness of >5 mm in postmenopausal women warrants further evaluation.[39] In cases of suspected mesenchymal tumors, ultrasound scanning is much less reliable in predicting malignancy. Sarcomas have been associated with certain features (mixed echogenic parts, central necrosis, and irregular vasculature on Doppler evaluation)[40]; none of these characteristics are specific to malignant tumors.[41] Resistance index and peak systolic velocity have emerged as sonographic measurements that could be used to distinguish between benign and malignant uterine mesenchymal tumors; however, the evidence is conflicting and limited to small case series.[42,43]

Magnetic resonance imaging (MRI) may be helpful in women in whom there is a suspicion of sarcoma. However, there are no definitive MRI characteristics that reliably have predicted the diagnosis of mesenchymal tumors. High signal intensity and ill-defined margins have been associated with leiomyosarcomas, but neither is a reliable indicator.[41,44–46] Small retrospective studies have demonstrated some promise in the use of both lactate dehydrogenase levels and diffusion-weighted MRI to distinguish uterine leiomyoma from leiomyosarcoma.[47] In a retrospective analysis of 51 cases, Thomassin-Naggara et al[48] reported on a model that incorporates signal intensity, mean apparent diffusion coefficient, and patient age to predict benign and malignant masses with 92% accuracy.

Because of the expense of positron emission tomography (PET) imaging and low incidence of uterine sarcomas, there are no large scale studies that have demonstrated efficacy of PET imaging in the diagnosis of these tumors. In a recent review of the PET imaging in the diagnosis and staging of uterine sarcoma, only 2 studies were found in the recent literature on the accuracy of diagnosis.[49–51] Fluorodeoxyglucose uptake varies between individual tumors, and standardized uptake value activity cannot distinguish reliably between benign and malignant masses. Although more studies are needed to clarify its use in the diagnosis of uterine sarcomas, the high cost of MRI will likely preclude its widespread use in the triage of uterine neoplasms.

Impact of morcellation

The concerns over morcellation include inadvertent trauma to surrounding structure, disruption of the pathologic specimen, and dispersion of tissue. Injuries have been reported to small and large bowel, vasculature, kidney, ureter, bladder, and diaphragm.[52] Disruption and dispersion of benign tissue has been associated with acute complications, such as peritonitis, intraabdominal abscesses, intestinal obstruction,[53] and chronic symptoms from disseminated fibroid tumors, endometriosis, or adenomyosis, which have the potential to transform into malignancy.[54]

One of the major concerns over morcellation of an occult cancer is delayed diagnosis because of misinterpretation of the initial pathologic specimen. Rivard et al[55] obtained 10 intact uterine specimens, 5 with endometrial adenocarcinoma and 5 without. After the intact specimens were processed, fixed, and analyzed, they were morcellated and re-reviewed. One of 5 specimens with known cancer was interpreted as benign, and none of the morcellated specimens could be staged. It is important to note that this study included only the interpretation of a single pathologist and that a similar study has not been conducted with uterine sarcomas. A recent case report of disseminated leiomyosarcoma shortly after receiving a diagnosis of benign leiomyomas raises concern for similar diagnostic challenges in the pathologic examination of morcellated leiomyosarcomas.[20] In this case, malignancy was diagnosed on re-review of the patient's original pathologic specimen. Unfortunately, what role hindsight played cannot be determined.

Another major concern over morcellation of an occult malignancy is the possibility of the seeding of cancer throughout the peritoneal cavity. To examine the frequency of this occurrence, 3 retrospective cohort studies have been conducted that included patients who underwent reexploratory surgery shortly after receiving a presumed diagnosis of stage I uterine sarcoma (Table 4).[14,18,19] In total, 9 of 31 patients who were presumed to have stage I leiomyosarcoma were found to have disseminated peritoneal disease at the time of reexploratory surgery. Five of 9 patients with smooth-muscle tumors of uncertain malignant potential also had evidence of abdominopelvic tumor nodules. In addition to these retrospective cohort studies, case reports have also described up-staging of sarcoma secondary to peritoneal spread after morcellation.[20–22]

Although these studies suggest that dispersed particles of malignant uterine tissue have biologic potential for neovascularization and growth, they cannot rule out the possibility that disseminated peritoneal disease may be due to incorrect initial staging, natural disease progression, or incorrect follow-up diagnosis. There was no uniformity in the method for assigning the initial stage, the interval between the first and second surgery, and the procedures used to differentiate peritoneal metastases from reactive fibroblastic proliferation. Furthermore, although all 3 studies commented on worse outcomes for patients with disseminated disease, they were not designed to demonstrate a causal relationship between morcellation and death. This is important to keep in mind, given that leiomyosarcoma, in particular, is an aggressive tumor at baseline. Of 3 studies to calculate higher recurrence rates and lower survival rates for patients with morcellated vs unmorcellated stage I leiomyosarcomas,[56–58] the only study to adjust for primary tumor

mitotic rate found no statistically significant difference in overall survival after making the adjustment.[58] Table 5 summaries these studies and their outcome measures.

At this time, the finding of disseminated peritoneal disease after morcellation of an occult leiomyosarcoma can be used most appropriately as a prognostic indicator. Other uses of this finding, such as to guide adjuvant therapies, are not supported by a critical review of the existing studies, which "suffer" from retrospective designs at single-institution referral centers, small numbers, and limited patient follow-up evaluation.

In contrast, the benefits of minimally invasive surgery are well-supported by level 1 data. A Cochrane systematic review, which included 27 randomized clinical trials that compared laparoscopic or vaginal hysterectomy to abdominal hysterectomy, found that women who underwent a minimally invasive surgery had significantly less blood loss, fewer incisional infections or febrile episodes, shorter hospital stays, and speedier return to normal activities.[59] In a Canadian study, patients with laparoscopic-assisted vaginal hysterectomy returned to normal activity and work 14 days sooner than their abdominal and vaginal hysterectomy counterparts.[60]

Epstein et al[61] recently reported on the financial impact of minimally invasive surgery on medical spending and employee absenteeism for 6 common minimally invasive procedures. Using insurance claims data with matched employer-provided absenteeism data, among the 7402 women who underwent "uterine fibroid resection," 4137 women underwent the traditional approach, and 3259 women had minimally invasive excisions. On average, those women who underwent the minimally invasive procedure had 11.5 fewer days absent from work and $1500 less in health plan spending per procedure. Based on estimates from ACOG, approximately 600,000 hysterectomies are done per year; in 2008, 10% of these were performed with a laparoscope.[62] In a hospital database analysis done by Wright et al[63] among women who underwent minimally invasive hysterectomy, >15% were performed with morcellation. With the use of these rough estimates and the assumption that the cases that involved morcellation were not possible laparoscopically otherwise, 9000 women (600,000 × 0.10 × 0.15) would have undergone laparotomy, yielding 99,000 more days absent from work per year and $13,500,000 more in health plan spending per year. The rapid adoption of robotic-assisted laparoscopic surgery in recent years likely makes this an underestimate in current surgical practice.

Other studies have demonstrated a significant decrease in postoperative narcotic use[64] and incisional hernias formation[65] and higher long-term quality-of-life scores on self-reported questionnaires[66] with a minimally invasive approach compared with an open approach. Given the abundance of high-quality data that compare the different approaches to hysterectomy, both the ACOG and the American Association of Gynecologic Laparoscopists have issued position papers supporting minimally invasive surgery for presumed benign disease in patients at low risk for malignancy.[9,67]

Surgical alternatives

Strategies to continue to allow surgeons to provide minimally invasive surgery to patients while minimizing the risk of the spread of occult malignancy involve refinement of

contained morcellation techniques. There are reports of power morcellation within an endoscopic bag[68,69]; however, current endoscopic bags were neither designed for this purpose nor sufficiently studied for this purpose. Notably, there are also mechanical morcellators without the rotational mechanism, which likely would reduce the intraperitoneal dissemination of tumor.

For specimens that are enlarged mildly but do not deliver easily because of nulliparity or obesity, transvaginal insertion of the anchor tissue retrieval system has been described for intact removal of specimens that were not delivered easily vaginally without the retrieval bag.[70] Specimens too large to be removed intact, even with the use of a retrieval bag may be candidates for extracorporeal morcellation.

Two extracorporeal morcellation techniques have been described to prevent spillage of specimen into the abdomen and to reduce vascular and bowel injuries that are associated with open power morcellation. In a study of 8 women, Favero et al[71] describe a vaginal morcellation approach in which they inserted a nylon with polyurethane Lapsac (Cook Medical, Bloomington, IN) into the pelvis transvaginally and used the Lapsac to retract the vaginal sidewalls and allow bisection of the contained tissue specimen for removal. They were able to remove all specimens successfully, but because the data only reached 3 months of follow up, time for disease-free recurrence is unknown. In a subsequent study, 12 women with endometrial cancer and uterine size >12 weeks underwent total laparoscopic hysterectomy with transvaginal uterine bisection within a sterile plastic wrapping bag that was inserted through a 12-mm port.[72] All patients had no evidence of local or distant recurrence at median follow up of 18 months. Serur and Lakhi[73] describe the transabdominal insertion of an endoscopic bag through a 20- to 30-mm incision, elevating the specimen above the abdominal incision and hand-morcellating the specimen for removal. This involves extension of one of the port site incisions but avoids a larger laparotomy. Both of these techniques keep the specimen contained within a laparoscopic bag, thus eliminating specimen spillage, as long as the integrity of the bag is not damaged inadvertently while hand-morcellating or bisecting the uterus. All port sites should be irrigated to avoid seeding and implantation of neoplastic tissue after extraction from laparoscopy or laparotomy incisions.

Advances in contained power morcellation techniques may provide improved speed of specimen removal while achieving equivalent safety to hand morcellation techniques. In a hospital simulation laboratory, contained tissue extraction of beef tongue specimens that were stained with indigo carmine dye did not result in any leakage or tissue dissemination when a 1-piece clear plastic 50 × 50–cm isolation bag was used.[74] Another recent report describes an enclosed, motor-actuated mesh that applies inward-directed cutting force to tissue that has been loaded into mesh within a protective bag.[75] This approach could be applied to a larger range in tissue size and density as compared with current power morcellators, while decreasing the risks of seeding and injury to other organs and structures. As contained power morcellation techniques gain approval for in vivo use, they likely will become the predominant approach with the advantages of decreased operative time while avoiding dissemination of endometriosis or malignancy and decreasing intraoperative injury as compared with current open morcellation techniques.

Summary and conclusion

Specific guidelines for the use of power morcellation may be of benefit while awaiting advances in preoperative diagnosis of sarcomas. Preoperative evaluation before hysterectomy includes cervical cytologic evidence and may include endometrial biopsy and pelvic imaging. If preoperative evaluation raises suspicion for malignancy, morcellation clearly should be avoided. Morcellation should be avoided in patients with a history of tamoxifen use, pelvic radiation, or increased genetic risk for malignancy. Surgeons should review surgical alternatives that include laparotomy, mini-laparotomy, and colpotomy with possible manual morcellation vaginally or within an endoscopic bag.

The impact of minimally invasive surgery on patient quality of life and the economic benefits of shorter recovery time and improved pain management should not be overlooked in gynecologic surgery. New surgical methods are being developed so that women with large uterine leiomyomata can still be offered laparoscopic surgery.

Acknowledgments

Supported by National Institutes of Health T-32 training grant (Ruth L. Kirschstein National Research Service Award Institutional Training Research Grant, 2T32 CA-060396-11).

REFERENCES

1. Steiner RA, Wight E, Tadir Y, Haller U. Electrical cutting device for laparoscopic removal of tissue from the abdominal cavity. Obstet Gynecol. 1993; 81:471–474. [PubMed: 8437807]
2. Forney JP, Buschbaum HJ. Classifying, staging, and treating uterine sarcomas. Contemp Obstet Gynecol. 1981; 18:47–69.
3. Kapp DS, Shin JY, Chan JK. Prognostic factors and survival in 1396 patients with uterine leiomyosarcomas: emphasis on impact of lymphadenectomy and oophorectomy. Cancer. 2008; 112:820–830. [PubMed: 18189292]
4. Abeler VM, Røyne O, Thoresen S, Danielsen HE, Nesland JM, Kristensen GB. Uterine sarcomas in Norway: a histopathological and prognostic survey of a total population from 1970 to 2000 including 419 patients. Histopathology. 2009; 54:355–364. [PubMed: 19236512]
5. Chan JK, Kawar NM, Shin JY, et al. Endometrial stromal sarcoma: a population-based analysis. Br J Cancer. 2008; 99:1210–1215. [PubMed: 18813312]
6. Arend R, Bagaria M, Lewin SN, et al. Long-term outcome and natural history of uterine adenosarcomas. Gynecol Oncol. 2010; 119:305–308. [PubMed: 20688363]
7. Tanner EJ, Garg K, Leitao MM, Soslow RA, Hensley ML. High grade undifferentiated uterine sarcoma: surgery, treatment, and survival outcomes. Gynecol Oncol. 2012; 127:27–31. [PubMed: 22750260]
8. American Cancer Society. Uterine sarcoma. 2014 Available at: http://www.cancer.org/acs/groups/cid/documents/webcontent/003145-pdf.pdf.
9. American Congress of Obsetricians and Gynecologists. Power morcellation and occult malignancy in gynecologic surgery. 2014 Available at: http://www.acog.org/Resources-And-Publications/Task-Force-and-Work-Group-Reports/Power-Morcellation-and-Occult-Malignancy-in-Gynecologic-Surgery.
10. Food and Drug Administration. Silver Spring, MD: US FDA; 2014. Quantitative assessment of the prevalence of unsuspected uterine sarcoma in women undergoing treatment of uterine fibroids. Available at: http://www.fda.gov/downloads/MedicalDevices/Safety/AlertsandNotices/UCM393589.pdf. [Accessed Aug. 4, 2014]

11. Leibsohn S, d'Ablaing G, Mishell DR, Schlaerth JB. Leiomyosarcoma in a series of hysterectomies performed for presumed uterine leiomyomas. Am J Obstet Gynecol. 1990; 162:968–976. [PubMed: 2327466]
12. Parker WH, Fu YS, Berek JS. Uterine sarcoma in patients operated on for presumed leiomyoma and rapidly growing leiomyoma. Obstet Gynecol. 1994; 83:414–418. [PubMed: 8127535]
13. Rowland M, Lesnock J, Edwards R, et al. Occult uterine cancer in patients undergoing laparoscopic hysterectomy with morcellation. Gynecol Oncol. 2012; 127:S29. [PubMed: 24989567]
14. Seidman MA, Oduyebo T, Muto MG, Crum CP, Nucci MR, Quade BJ. Peritoneal dissemination complicating morcellation of uterine mesenchymal neoplasms. PLoS One. 2012; 7:e50058. [PubMed: 23189178]
15. Ehdaivand S, Simon RA, Sung CJ, Steinhoff MM, Lawrence WD, Quddus MR. Incidental gynecologic neoplasms in morcellated uterine specimens: a case series with follow-up. Hum Pathol. 2014; 45:2311–2317. [PubMed: 25257577]
16. Lawrence RS, Mickalide AD. Preventive services in clinical practice: designing the periodic health examination. JAMA. 1987; 257:2205–2207. [PubMed: 3560403]
17. Zivanovic O, Leitao MM, Iasonos A, et al. Stage-specific outcomes of patients with uterine leiomyosarcoma: a comparison of the international Federation of gynecology and obstetrics and american joint committee on cancer staging systems. J Clin Oncol. 2009; 27:2066–2072. [PubMed: 19255317]
18. Einstein MH, Barakat RR, Chi DS, et al. Management of uterine malignancy found incidentally after supracervical hysterectomy or uterine morcellation for presumed benign disease. Int J Gynecol Cancer. 2008; 18:1065–1070. [PubMed: 17986239]
19. Oduyebo T, Rauh-Hain AJ, Meserve EE, et al. The value of re-exploration in patients with inadvertently morcellated uterine sarcoma. Gynecol Oncol. 2014; 132:360–365. [PubMed: 24296345]
20. Anupama R, Ahmad SZ, Kuriakose S, Vijaykumar DK, Pavithran K, Seethalekshmy NV. Disseminated peritoneal leiomyosarcomas after laparoscopic "myomectomy" and morcellation. J Minim Invasive Gynecol. 2011; 18:386–389. [PubMed: 21545964]
21. Della Badia C, Karini H. Endometrial stromal sarcoma diagnosed after uterine morcellation in laparoscopic supracervical hysterectomy. J Minim Invasive Gynecol. 2010; 17:791–793. [PubMed: 20955991]
22. Rekha W, Amita M, Sudeep G, Hemant T. Unexpected complication of uterine myoma morcellation. Aust N Z J Obstet Gynaecol. 2005; 45:248–249. [PubMed: 15904454]
23. Dijkhuizen FP, Mol BW, Brölmann HA, Heintz AP. The accuracy of endometrial sampling in the diagnosis of patients with endometrial carcinoma and hyperplasia: a meta-analysis. Cancer. 2000; 89:1765–1772. [PubMed: 11042572]
24. Clark TJ, Mann CH, Shah N, Khan KS, Song F, Gupta JK. Accuracy of outpatient endometrial biopsy in the diagnosis of endometrial cancer: a systematic quantitative review. BJOG. 2002; 109:313–321. [PubMed: 11950187]
25. Bansal N, Herzog TJ, Burke W, Cohen CJ, Wright JD. The utility of preoperative endometrial sampling for the detection of uterine sarcomas. Gynecol Oncol. 2008; 110:43–48. [PubMed: 18445505]
26. Montague AC, Swartz DP, Woodruff JD. Sarcoma arising in a leiomyoma of the uterus: factors influencing prognosis. Am J Obstet Gynecol. 1965; 92:421–427. [PubMed: 14292457]
27. Baird DD, Garrett TA, Laughlin SK, Davis B, Semelka RC, Peddada SD. Short-term change in growth of uterine leiomyoma: tumor growth spurts. Fertil Steril. 2011; 95:242–246. [PubMed: 21168581]
28. DeWaay DJ, Syrop CH, Nygaard IE, Davis WA, Van Voorhis BJ. Natural history of uterine polyps and leiomyomata. Obstet Gynecol. 2002; 100:3–7. [PubMed: 12100797]
29. Peddada SD, Laughlin SK, Miner K, et al. Growth of uterine leiomyomata among premenopausal black and white women. Proc Natl Acad Sci U S A. 2008; 105:19887–19892. [PubMed: 19047643]

30. Leung F, Terzibachian JJ, Gay C, et al. Hysterectomies performed for presumed leiomyomas: should the fear of leiomyosarcoma make us apprehend non laparotomic surgical routes? Gynecol Obstet Fertil. 2009; 37:109–114. [PubMed: 19200764]
31. Brooks SE, Zhan M, Cote T, Baquet CR. Surveillance, epidemiology, and end results analysis of 2677 cases of uterine sarcoma 1989–1999. Gynecol Oncol. 2004; 93:204–208. [PubMed: 15047237]
32. Templeman C, Marshall SF, Clarke CA, et al. Risk factors for surgically removed fibroids in a large cohort of teachers. Fertil Steril. 2009; 92:1436–1446. [PubMed: 19019355]
33. Marshall LM, Spiegelman D, Barbieri RL, et al. Variation in the incidence of uterine leiomyoma among premenopausal women by age and race. Obstet Gynecol. 1997; 90:967–973. [PubMed: 9397113]
34. Wickerham DL, Fisher B, Wolmark N, et al. Association of tamoxifen and uterine sarcoma. J Clin Oncol. 2002; 20:2758–2760. [PubMed: 12039943]
35. Moinfar F, Azodi M, Tavassoli FA. Uterine sarcomas. Pathology. 2007; 39:55–71. [PubMed: 17365823]
36. Launonen V, Vierimaa O, Kiuru M, et al. Inherited susceptibility to uterine leiomyomas and renal cell cancer. Proc Natl Acad Sci U S A. 2001; 98:3387–3392. [PubMed: 11248088]
37. Toro JR, Nickerson ML, Wei MH, et al. Mutations in the fumarate hydratase gene cause hereditary leiomyomatosis and renal cell cancer in families in North America. Am J Hum Genet. 2003; 73:95–106. [PubMed: 12772087]
38. Yu CL, Tucker MA, Abramson DH, et al. Cause-specific mortality in long-term survivors of retinoblastoma. J Natl Cancer Inst. 2009; 101:581–591. [PubMed: 19351917]
39. Timmermans A, Opmeer BC, Khan KS, et al. Endometrial thickness measurement for detecting endometrial cancer in women with postmenopausal bleeding: a systematic review and meta-analysis. Obstet Gynecol. 2010; 116:160–167. [PubMed: 20567183]
40. Exacoustos C, Romanini ME, Amadio A, et al. Can gray-scale and color Doppler sonography differentiate between uterine leiomyosarcoma and leiomyoma? J Clin Ultrasound. 2007; 35:449–457. [PubMed: 17636502]
41. Amant F, Coosemans A, Debiec-Rychter M, Timmerman D, Vergote I. Clinical management of uterine sarcomas. Lancet Oncol. 2009; 10:1188–1198. [PubMed: 19959075]
42. Hata K, Hata T, Maruyama R, Hirai M. Uterine sarcoma: can it be differentiated from uterine leiomyoma with Doppler ultrasonography? A preliminary report. Ultrasound Obstet Gynecol. 1997; 9:101–104. [PubMed: 9132251]
43. Szabó I, Szánthó A, Csabay L, Csapó Z, Szirmai K, Papp Z. Color Doppler ultrasonography in the differentiation of uterine sarcomas from uterine leiomyomas. Eur J Gynaecol Oncol. 2002; 23:29–34. [PubMed: 11876388]
44. Schwartz LB, Zawin M, Carcangiu ML, Lange R, McCarthy S. Does pelvic magnetic resonance imaging differentiate among the histologic subtypes of uterine leiomyomata? Fertil Steril. 1998; 70:580–587. [PubMed: 9757898]
45. Tanaka YO, Nishida M, Tsunoda H, Okamoto Y, Yoshikawa H. Smooth muscle tumors of uncertain malignant potential and leiomyosarcomas of the uterus: MR findings. J Magn Reson Imaging. 2004; 20:998–1007. [PubMed: 15558559]
46. Sato K, Yuasa N, Fujita M, Fukushima Y. Clinical application of diffusion-weighted imaging for preoperative differentiation between uterine leiomyoma and leiomyosarcoma. Am J Obstet Gynecol. 2014; 210:368.e1–368.e8. [PubMed: 24368137]
47. Goto A, Takeuchi S, Sugimura K, Maruo T. Usefulness of Gd-DTPA contrast-enhanced dynamic MRI and serum determination of LDH and its isozymes in the differential diagnosis of leiomyosarcoma from degenerated leiomyoma of the uterus. Int J Gynecol Cancer. 2002; 12:354–361. [PubMed: 12144683]
48. Thomassin-Naggara I, Dechoux S, Bonneau C, et al. How to differentiate benign from malignant myometrial tumours using MR imaging. Eur Radiol. 2013; 23:2306–2314. [PubMed: 23563602]
49. Sadeghi R, Zakavi SR, Hasanzadeh M, Treglia G, Giovanella L, Kadkhodayan S. Diagnostic performance of fluorine-18-fluorodeoxyglucose positron emission tomography imaging in uterine

sarcomas: systematic review and meta-analysis of the literature. Int J Gynecol Cancer. 2013; 23:1349–1356. [PubMed: 23945203]

50. Yamane T, Takaoka A, Kita M, Imai Y, Senda M. 18F-FLT PET performs better than 18F-FDG PET in differentiating malignant uterine corpus tumors from benign leiomyoma. Ann Nucl Med. 2012; 26:478–484. [PubMed: 22477262]
51. Nagamatsu A, Umesaki N, Li L, Tanaka T. Use of 18F-fluorodeoxyglucose positron emission tomography for diagnosis of uterine sarcomas. Oncol Rep. 2010; 23:1069–1076. [PubMed: 20204293]
52. Milad MP, Milad EA. Laparoscopic morcellator-related complications. J Minim Invasive Gynecol. 2014; 21:486–491. [PubMed: 24333632]
53. Lieng M, Istre O, Busund B, Qvigstad E. Severe complications caused by retained tissue in laparoscopic supracervical hysterectomy. J Minim Invasive Gynecol. 2006; 13:231–233. [PubMed: 16698531]
54. Heller DS, Cracchiolo B. Peritoneal nodules after laparoscopic surgery with uterine morcellation: review of a rare complication. J Minim Invasive Gynecol. 2014; 21:384–388. [PubMed: 24462597]
55. Rivard C, Salhadar A, Kenton K. New challenges in detecting, grading, and staging endometrial cancer after uterine morcellation. J Minim Invasive Gynecol. 2012; 19:313–316. [PubMed: 22417903]
56. Perri T, Korach J, Sadetzki S, Oberman B, Fridman E, Ben-Baruch G. Uterine leiomyosarcoma: does the primary surgical procedure matter? Int J Gynecol Cancer. 2009; 19:257–260. [PubMed: 19396005]
57. Park JY, Park SK, Kim DY, et al. The impact of tumor morcellation during surgery on the prognosis of patients with apparently early uterine leiomyosarcoma. Gynecol Oncol. 2011; 122:255–259. [PubMed: 21565389]
58. George S, Barysauskas C, Serrano C, et al. Retrospective cohort study evaluating the impact of intraperitoneal morcellation on outcomes of localized uterine leiomyosarcoma. Cancer. 2014; 120:3154–3158. [PubMed: 24923260]
59. Nieboer TE, Johnson N, Lethaby A, et al. Surgical approach to hysterectomy for benign gynaecological disease. Cochrane Database Syst Rev. 2009:CD003677. [PubMed: 19588344]
60. Lenihan JP, Kovanda C, Cammarano C. Comparison of laparoscopic-assisted vaginal hysterectomy with traditional hysterectomy for cost-effectiveness to employers. Am J Obstet Gynecol. 2004; 190:1714–1722. [PubMed: 15284779]
61. Epstein AJ, Groeneveld PW, Harhay MO, Yang F, Polsky D. Impact of minimally invasive surgery on medical spending and employee absenteeism. JAMA Surg. 2013; 148:641–647. [PubMed: 23552709]
62. American Congress of Obstetricians and Gynecologists. Women's health stats & facts: 2011. Washington, DC: ACOG; 2011. Available at: http://www.acog.org/w/media/NewsRoom/MediaKit.pdf. [Accessed Aug. 13, 2014]
63. Wright JD, Tergas AI, Burke WM, et al. Uterine pathology in women undergoing minimally invasive hysterectomy using morcellation. JAMA. 2014; 312:1253–1255. [PubMed: 25051495]
64. Kongwattanakul K, Khampitak K. Comparison of laparoscopically assisted vaginal hysterectomy and abdominal hysterectomy: a randomized controlled trial. J Minim Invasive Gynecol. 2012; 19:89–94. [PubMed: 22133703]
65. Le Huu Nho R, Mege D, Ouaïssi M, Sielezneff I, Sastre B. Incidence and prevention of ventral incisional hernia. J Visc Surg. 2012; 149:e3–e14. [PubMed: 23142402]
66. Nieboer TE, Hendriks JC, Bongers MY, Vierhout ME, Kluivers KB. Quality of life after laparoscopic and abdominal hysterectomy: a randomized controlled trial. Obstet Gynecol. 2012; 119:85–91. [PubMed: 22183215]
67. AAGL Advancing Minimally Invasive Gynecology Worldwide. AAGL practice report: morcellation during uterine tissue extraction. J Minim Invasive Gynecol. 2014; 21:517–530. [PubMed: 24865630]
68. Einarsson JI, Cohen SL, Fuchs N, Wang KC. In-bag morcellation. J Minim Invasive Gynecol. 2014; 21:951–953. [PubMed: 24769447]

69. Cohen SL, Einarsson JI, Wang KC, et al. Contained power morcellation within an insufflated isolation bag. Obstet Gynecol. 2014; 124:491–497. [PubMed: 25162248]

70. Wyman A, Fuhrig L, Bedaiwy MA, Debernardo R, Coffey G. A novel technique for transvaginal retrieval of enlarged pelvic viscera during minimally invasive surgery. J Minim Invasive Surg. 2012; 2012:454120.

71. Favero G, Anton C, Silva e Silva A, et al. Vaginal morcellation: a new strategy for large gynecological malignant tumor extraction: a pilot study. Gynecol Oncol. 2012; 126:443–447. [PubMed: 22634019]

72. Montella F, Riboni F, Cosma S, et al. A safe method of vaginal longitudinal morcellation of bulky uterus with endometrial cancer in a bag at laparoscopy. Surg Endosc. 2014; 28:1949–1953. [PubMed: 24566741]

73. Serur E, Lakhi N. Laparoscopic hysterectomy with manual morcellation of the uterus: an original technique that permits the safe and quick removal of a large uterus. Am J Obstet Gynecol. 2011; 204:566.e1–566.e2. [PubMed: 21752759]

74. Cohen SL, Greenberg JA, Wang KC, et al. Risk of leakage and tissue dissemination with various contained tissue extraction (CTE) techniques: an in vitro pilot study. J Minim Invasive Gynecol. 2014; 21:935–939. [PubMed: 24928740]

75. Isakov A, Murdaugh KM, Burke W, et al. A new laparoscopic morcellator using an actuated wire mesh and bag. J Med Devices. 2014; 8:7.

TABLE 1

Early-stage survival of uterine sarcomas

Variable	Year published	Stage	n	Survival outcome
Leiomyosarcoma				
Kapp et al[3]	2008	I	951	5-yr DSS = 75.8%
		II	43	5-yr DSS = 60.1%
Abeler et al[4]	2009	I	193	5-yr OS = 51%
		II	36	5-yr OS = 25%
Endometrial stromal sarcoma				
Chan et al[5]	2008	I–II	540	6-yr DSS = 89%
Abeler et al[4]	2009	I	56	5-yr OS = 84%
		II	21	5-yr OS = 62%
Adenosarcoma				
Arend et al[6]	2010	I	327	5-yr OS = 79%
Undifferentiated uterine sarcoma				
Abeler et al[4]	2009	I	14	5-yr OS = 57%
		II	5	5-yr OS = 0%
Tanner et al[7]	2012	I	7	Median OS = 26.8 mo

DSS, disease specific survival; *OS*, overall survival.

Liu. Critical assessment of morcellation. Am J Obstet Gynecol 2015.

TABLE 2

Risk of unsuspected uterine sarcomas at the time of surgical excision, United States, 1980–2014

Author	Year published	Procedure	n	Cases of sarcomas, n	Risk of uterine sarcoma, % (95% confidence interval)	Level of evidence
Leibsohn et al[11]	1990	Hysterectomy	1429	7	0.5 (0.1–0.9)	3
Parker et al[12]	1994	Hysterectomy or myomectomy	1332	4	0.2 (0.0–0.5)	3
Rowland et al[13]	2011	Hysterectomy	1115	8	0.5 (0.1–0.8)	3
Seidman et al[14]	2012	Myomectomy	1091	2	0.2 (0.0–0.4)	3
Ehdaivand et al[15]	2014	Hysterectomy	352	3	0.8 (0.2–2.5)	3
TOTAL			5319	24	0.5 (0.1–0.7)	

Liu. Critical assessment of morcellation. Am J Obstet Gynecol 2015.

TABLE 3

Utility of imaging modalities in the diagnosis of uterine sarcomas

Variable	Year published	n	Cases of sarcoma, n	Measurement of interest	Sensitivity, %	Specificity, %	Level of evidence
Ultrasound scan							
Hata et al[42]	1997	46	5	Intratumoral PSV 41.0 cm/sec	80	97	3
Szabo et al[43]	2002	129	12	Intratumoral RI <0.5	67	87	3
Exacoustos et al[40]	2007	257	8	Increased central and peripheral vascularity	100	86	3
Magnetic resonance imaging							
Schwartz et al[44]	1998	45	4	Ill-defined margins	100	100	3
Tanaka et al[45]	2004	24	12	High signal intensity of T2 and T1WI	73	100	3
Sato et al[46]	2014	81	5	Signal intensity on diffusion weighted imaging + ADC	100	99	3
Positron emission tomography/computerized tomography							
Nagamatsu et al[51]	2009	53	10	SUV >3.0	100	73	3
Yamane et al[50]	2012	15	3	SUV >4.32	100	63	3

ADC, apparent diffusion coefficient; *PSV*, peak systolic velocity; *RI*, resistance index; *SUV*, standardized uptake value.

Liu. Critical assessment of morcellation. Am J Obstet Gynecol 2015.

TABLE 4

Disseminated disease after morcellation of uterine sarcomas

Author	Year published	Study years	n	Cases of sarcoma, n	Cases of documented dissemination on reexploration
Einstein et al[18]	2008	2000–2006	—	17[a]	2
Seidman et al[14]	2012	2005–2010	1091	7	4
Oduyebo et al[19]	2014	2005–2012	—	15[b]	3

[a]Of 17 cases, 13 women underwent reexploratory surgery;

[b]Of 15 cases, 11 women underwent reexploratory surgery.

Liu. Critical assessment of morcellation. Am J Obstet Gynecol 2015.

TABLE 5

Cases of uterine sarcoma and outcomes after morcellation

Author	Year published	Study years	n	Nonmorcellated cases, n	Morcellated cases, n	Outcome measure	Level of evidence
Perri et al[56]	2009	1965–2005	37	21	16	Hazard ratio, 2.8 (95% CI, 1.02–7.67)[a]	II-3
Park et al[57]	2011	1989–2010	56	31	25	Odds ratio, 3.11 (95% CI,1.07–9.06)[b]	II-3
George et al[58]	2014	2007–2012	58	39	19	Hazard ratio, 3.18 (95% CI,1.5–6.8)[c]	II-3

CI, confidence interval.

[a]Overall survival, multivariate adjusted model, $P = .04$;

[b]Overall survival, multivariate adjusted model, $P = .038$;

[c]Recurrence-free survival, multivariate adjusted model, $P = .003$.

Liu. Critical assessment of morcellation. Am J Obstet Gynecol 2015.