# Use of augmented reality in laparoscopic gynecology to visualize myomas

Nicolas Bourdel, M.D.,[a,b] Toby Collins, Ph.D.,[b] Daniel Pizarro, Ph.D.,[b] Clement Debize,[b] Anne-sophie Grémeau, M.D.,[a] Adrien Bartoli, Ph.D.,[b] and Michel Canis, M.D., Ph.D.[a,b]

[a] Department of Gynecologic Surgery, Centre Hospitalier de l'Université Estaing Clermont-Ferrand; and [b] ALCoV, Image Science for Interventional Techniques (Unité Mixte de Recherche 6284, Centre National de la Recherche Scientifique), University of Auvergne, Clermont-Ferrand, France

**Objective:** To report the use of augmented reality (AR) in gynecology.
**Design:** AR is a surgical guidance technology that enables important hidden surface structures to be visualized in endoscopic images. AR has been used for other organs, but never in gynecology and never with a very mobile organ like the uterus. We have developed a new AR approach specifically for uterine surgery and demonstrated its use for myomectomy.
**Setting:** Tertiary university hospital.
**Patient(s):** Three patients with one, two, and multiple myomas, respectively.
**Intervention(s):** AR was used during laparoscopy to localize the myomas.
**Main Outcome Measure(s):** Three-dimensional (3D) models of the patient's uterus and myomas were constructed before surgery from T2-weighted magnetic resonance imaging. The intraoperative 3D shape of the uterus was determined. These models were automatically aligned and "fused" with the laparoscopic video in real time.
**Result(s):** The live fused video made the uterus appear semitransparent, and the surgeon can see the location of the myoma in real time while moving the laparoscope and the uterus. With this information, the surgeon can easily and quickly decide on how best to access the myoma.
**Conclusion(s):** We developed an AR system for gynecologic surgery and have used it to improve laparoscopic myomectomy. Technically, the software we developed is very different to approaches tried for other organs, and it can handle significant challenges, including image blur, fast motion, and partial views of the organ. (Fertil Steril® 2016;■:■–■. ©2016 by American Society for Reproductive Medicine.)
**Key Words:** Gynecologic surgery, laparoscopy, augmented reality, myomectomy, MRI

**Discuss:** You can discuss this article with its authors and with other ASRM members at https://www.fertstertdialog.com/users/16110-fertility-and-sterility/posts/14016-22248

Augmented Reality (AR) is a general concept that allows a surgeon to see subsurface structures in an endoscopic video. This works by overlaying information from another modality, such as magnetic resonance imaging (MRI) and fusing it with the endoscopic images (1, 2). AR systems have been developed to assist surgical procedures including liver resection (2) and neurosurgical navigation (3). Despite progress, automatic real-time AR is technically challenging and has never been attempted on a very mobile organ like the uterus. We have developed a new approach that can handle mobile organs. We reported recently the usefulness of AR for localizing myomas in a uterine model (1). We here report its use for laparoscopic myoma localization. Myomectomy can be challenging for cases where the myoma is small- to medium-sized and does not significantly change the uterus' outer shape. Because AR can show the exact positions of hidden subsurface structures, it has great potential to guide the surgeon in these cases.

## MATERIALS AND METHODS

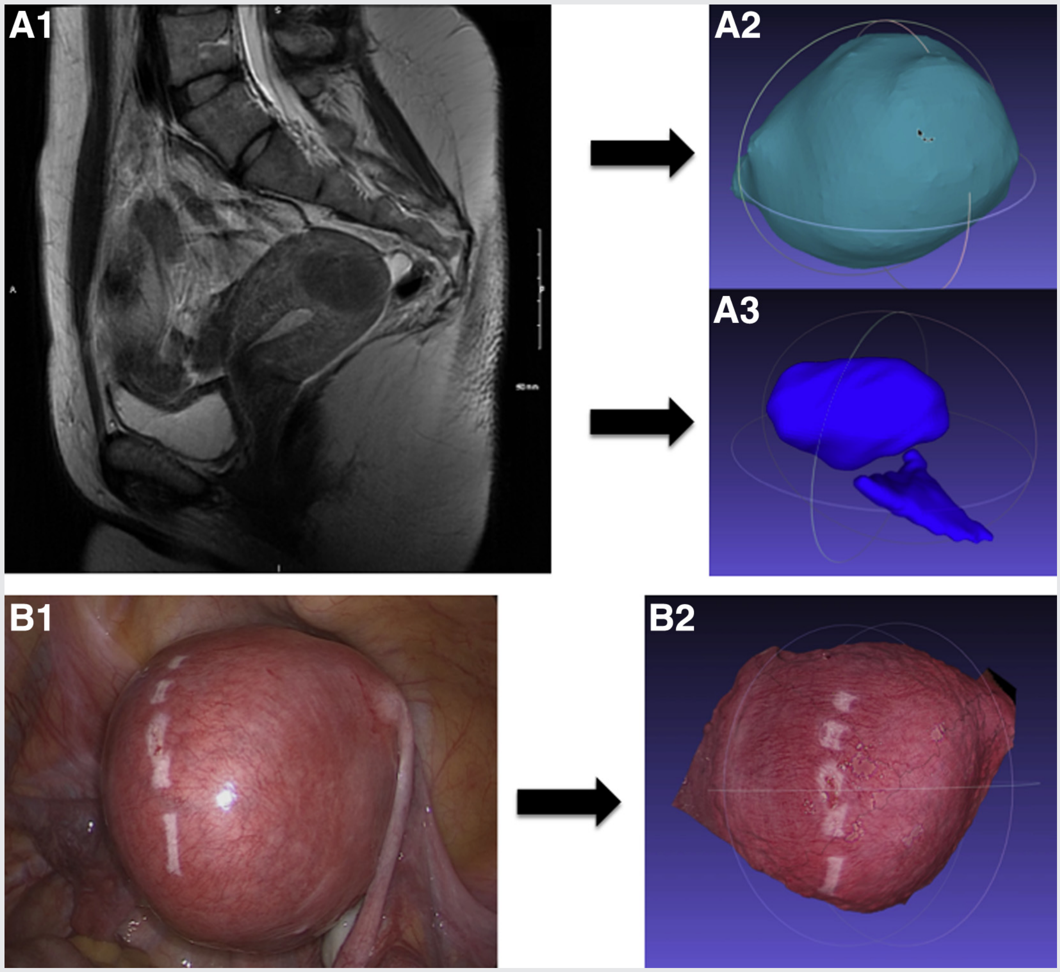
A 38-year-old woman with a 6-cm intramural uterine myoma on the posterior part of the fundus underwent a laparoscopic myomectomy (Video 1, available online at www.fertstert.org). Signed consent was obtained, which included a clause of no modification of her surgery. This patient was chosen as the first case for using AR because of the simplicity of the procedure and the

Received April 13, 2016; revised December 14, 2016; accepted December 16, 2016.
N.B. has nothing to disclose. T.C. has nothing to disclose. D.P. has nothing to disclose. C.D. has nothing to disclose. A.-s.G. has nothing to disclose. A.B. has nothing to disclose. M.C. has nothing to disclose.
Reprint requests: Nicolas Bourdel, M.D., Department of Gynecologic Surgery, CHU Estaing Clermont-Ferrand, 1, place Lucie Aubrac, Clermont-Ferrand 63000, France (E-mail: micolas.bourdel@gmail.com).

Fertility and Sterility® Vol. ■, No. ■, ■ 2017 0015-0282/$36.00

http://dx.doi.org/10.1016/j.fertnstert.2016.12.016

FIGURE 1




(**A**) With the use of (**A1**) T2-weighted magnetic resonance imaging (MRI), preoperative construction of the 3D mesh models: (**A2**) uterus and (**A3**) myoma and uterine cavity. (**B**) Intraoperative 3D mesh model construction: (**B1**) laparoscopic view; (**B2**) mesh model.

*Bourdel. Augmented reality for gynecology. Fertil Steril 2016.*

demonstrability of the use of AR. The AR system was then used in two other patients with, respectively, two and multiple myomas. Signed consents were obtained, which included clauses of no modification of the surgery.

Before surgery, the outer surface of the uterus, uterine cavity, and myoma were delimited according to a preoperative T2-weighted MRI (Fig. 1; Video 1). This segmentation phase was performed with the use of an interactive segmentation software (Medical Imaging Interaction Toolkit; German Cancer Research Center).

A standard laparoscopic technique and a standard laparoscopic set were used with a 0° laparoscope (Spies; Karl Storz). During surgery, AR software was then activated to visualize the myoma. To achieve real-time AR (>10 frames per second), our system processed the uterus in three distinct phases (4, 5) (Fig. 1; Video 1). In the first phase, the intraoperative 3D shape of the uterus was determined by our software, which involves a process called "dense structure-from-motion" (4, 5) (Fig. 1). This works by capturing a small number of images of the uterus taken from different viewpoints and then automatically reconstructing a 3D intraoperative mesh model (Video 1). In the second stage, the preoperative uterus model was aligned to the intraoperative 3D model by means of a semiautomatic registration process (5). This involved a small amount of manual input to mark the organ's boundary contours. The third stage is what we call the tracking and fusion stage. This stage runs in real-time and aligns the preoperative models to the live laparoscopic video.

## RESULTS

The aligned models are blended with each video frame to give the impression that the uterus is semitransparent, and the surgeon can see the exact location of the myoma inside it (Video 1). For the first patient, the incision was confirmed after having accurately localized the myoma with the use of AR. Myomectomy was then performed with the use of a classic laparoscopic technique. In the two other patients, AR allowed localizing multiple myomas. For the last patient, the uterine cavity also is displayed in the video.

## DISCUSSION

We report the use of AR in gynecology. To our knowledge there is no other report of the use of AR in gynecology. One of the most likely reasons is the technical challenge it presents, because the uterus and ovaries are very mobile organs. In contrast to AR systems previously reported for other organs, our AR system requires no additional laparoscopic hardware (only a standard monocular laparoscope is needed). The software runs on a standard PC (Intel i7 desktop PC) (5). It does not require artificial landmarks, and unlike other systems (6, 7) it does not fail with motion blur or when the laparoscope is removed (e.g., for cleaning) and then reinserted. Our system solves the most challenging stage: the tracking and fusion phase in real time (1).

Our goal is to use AR to improve surgery of small- or medium-sized intramural myomas that can not be easily localized during laparoscopy, by fusing the laparoscopic images with preoperative MRI. The localization of myomas during laparoscopy can be very simple when the deformation of the serosa is present, but when they do not significantly change the surface of the uterus (types 2–4 of the International Federation of Gynecology and Obstetrics classification system [8]) or are in multiple locations, these myomas are not always easy to correctly localize (9). Moreover, with the increased use of ulipristal, myomas are more often soft, decreasing the tactile feedback that could help the surgeon. With a decrease in size, the number of myomas potentially operated on with the use of laparoscopy (instead of laparotomy) also increases (10, 11). Small myomas are probably more often left in place after laparoscopy (because there is no tactile feedback) compared with laparotomy, and recurrence after laparoscopic myomectomy has been described as more likely than after myomectomy with the use of laparotomy (9). In contrast, robotic myomectomy requires more technical improvement, because the residual fibroid volume was described to be as much as five times greater than after laparotomy (12), and the recurrence rate 5 years after laparoscopic myomectomy reaches 50% or more in many series reported in the literature. The current way to localize myomas seems to be inadequate for small and/or multiple myomas. Our system allows visualizing the positions of these myomas and can be applied in robotic surgery as well. We reported previously (1) the better accuracy in the localization of small myomas when using AR in a uterine model.

The only time-consuming aspect of our system is in the preoperative stage of MRI segmentation. Automation of this phase will probably be possible in the near future (13). The intraoperative phase (construction of the 3D intraoperative model and the registration phase) is a quick procedure, taking $<5$ minutes. The cost-effectiveness of MRI (compared with ultrasound) has to be proved. However, MRI is the most sensitive modality to identify myomas (particularly small ones) and to differentiate leiomyoma from adenomyosis, and it is less operator dependent.

In the first case, we augmented only the laparoscopic images of the myoma. In the third case (Video 1), the uterine cavity was shown on the laparoscopic image. The next step will be to include the vascularization of the myoma. AR could also improve planning the surgery: Our system can be used for visualizing during surgery a preoperative optimized incision plan (which takes into account vascularization, access to all the myomas, tool ports, localization of the uterine cavity, insertion of the tube, etc.). Myomas are simple tumor models to develop AR systems. In other indications (endometriosis, oncologic procedure, uterine scar niche, etc.), AR could be helpful to localize not only the pathology itself, but also all the anatomic landmarks and surrounding organs (ureter, main vessels, rectum).

Our AR system overlays important additional information to enhance uterine surgery without additional laparoscopic hardware. We have developed software that is very different from approaches in nongynecologic uses of AR to account for the mobility of the uterus. Our system could be a way to make laparoscopic myomectomy easier, safer, and faster. The technique could be used in most gynecologic surgeries with slight adaptation allowing localization of anatomic landmarks (14).

## REFERENCES

1. Bourdel N, Collins T, Pizarro D, Bartoli A, da Ines D, Perreira B, et al. Augmented reality in gynecologic surgery: evaluation of potential benefits for myomectomy in an experimental uterine model. Surg Endosc 2017;31:456–61.
2. Soler L, Nicolau S, Pessaux P, Mutter D, Marescaux J. Real-time 3D image reconstruction guidance in liver resection surgery. Hepatobiliary Surg Nutr 2014;3:73–81.
3. Grimson WL, Ettinger GJ, White SJ, Lozano-Perez T, Wells WM, Kikinis R. An automatic registration method for frameless stereotaxy, image guided surgery, and enhanced reality visualization. IEEE Trans Med Imaging 1996;15:129–40.
4. Collins T, Pizarro D, Bartoli A, Canis M, Bourdel N. Computer-Assisted Laparoscopic myomectomy by augmenting the uterus with pre-operative MRI data. 2014 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2014:243–8.
5. Collins T, Pizarro D, Bartoli A, Canis M, Bourdel N. Real-time wide-baseline registration of the uterus in monocular laparoscopic videos. MICCAI conference, Nagoya, Japan, 2013.
6. Nakamoto M, Nakada K, Sato Y, Konishi K, Hashizume M, Tamura S. Intraoperative magnetic tracker calibration using a magneto-optic hybrid tracker for 3-D ultrasound-based navigation in laparoscopic surgery. IEEE Trans Med Imaging 2008;27:255–70.
7. Marescaux J, Rubino F, Arenas M, Mutter D, Soler L. Augmented-reality-assisted laparoscopic adrenalectomy. JAMA 2004;292:2214–5.
8. Munro MG, Critchley HO, Broder MS, Fraser IS. FIGO classification system (PALM-COEIN) for causes of abnormal uterine bleeding in nongravid women of reproductive age. Int J Gynaecol Obstet 2011;113:3–13.
9. Desai P, Patel P. Fibroids, infertility and laparoscopic myomectomy. J Gynecol Endosc Surg 2011;2:36–42.
10. Donnez J, Dolmans MM. Uterine fibroid management: from the present to the future. Hum Reprod Update 2016;22:665–86.
11. Trefoux Bourdet A, Luton D, Koskas M. Clinical utility of ulipristal acetate for the treatment of uterine fibroids: current evidence. Int J Womens Health 2015;7:321–30.
12. Griffin L, Feinglass J, Garrett A, Henson A, Cohen L, Chaudhari A, et al. Postoperative outcomes after robotic versus abdominal myomectomy. JSLS 2013;17:407–13.
13. de Leener B, Kadoury S, Cohen-Adad J. Robust, accurate and fast automatic segmentation of the spinal cord. Neuroimage 2014;98:528–36.
14. Bartoli A, Collins T, Bourdel N, Canis M. Computer assisted minimally invasive surgery: is medical computer vision the answer to improving laparosurgery? Med Hypotheses 2012;79:858–63.