Advanced 3D Ultrasound Incorporating Fly Thru Virtual Imaging Promotes the Concept of Ultrasound Hysteroscopy

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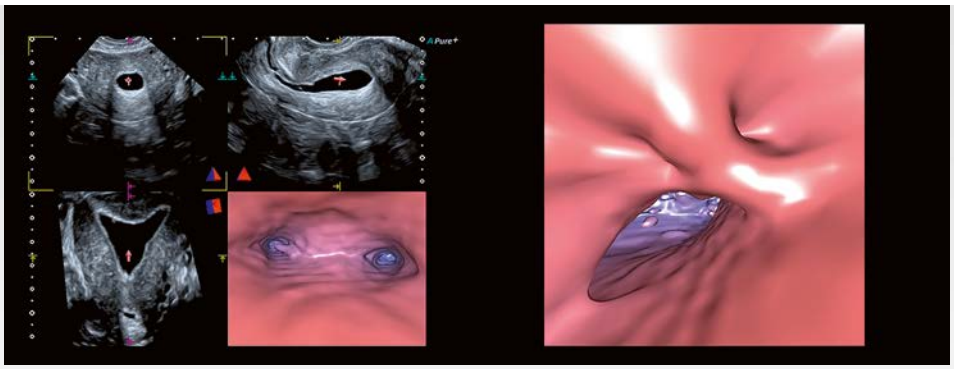
Introduction

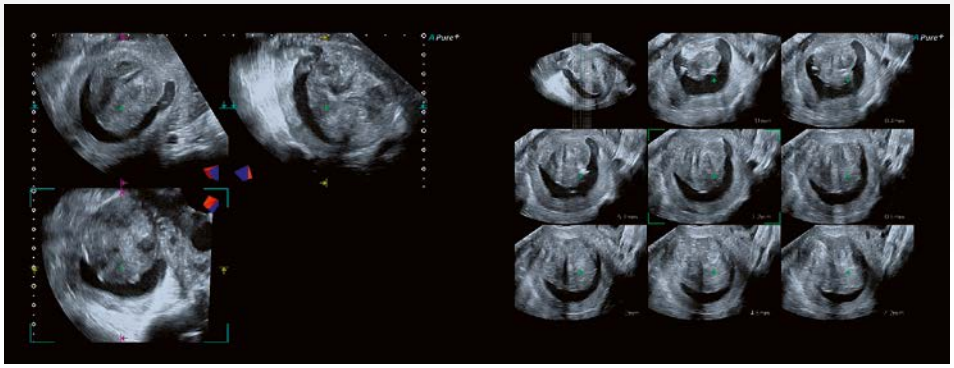
Conventional hysteroscopy remains the so-called "gold standard" for examination of the uterine cavity and in particular investigation of abnormal uterine bleeding. However, despite improvements in instrumentation and procedural techniques, it remains a relatively invasive, costly procedure. It still involves in many units general anaesthesia or at least heavy patient sedation, often a range of clinical, nursing or technical personnel and is usually carried out in a theatre setting. In addition, it is not unreasonable to question the number of cases reporting "normal findings" thereby suggesting a need to reduce unnecessary surgical procedures as such.

Current developments in 2D and 3D transvaginal ultrasound offer increasingly more detailed assessment of the pelvic organs and gynaecological disease. The utilisation of high-resolution ultrasound imaging as part of saline infusion studies of the uterine cavity greatly enhances the ability to identify or exclude associated pathology. The recent introduction of Canon Medical Systems 3D virtual imaging (Fly Thru) technology significantly increases diagnostic confidence in this respect. It provides a very effective, non-invasive alternative to conventional hysteroscopy and serves to select those patients who would indeed require surgical procedure. It proves less invasive and better tolerated by patients and has significant positive financial implications certainly within the public sector. Ultrasound hysteroscopy presents virtually no post-procedure complications, unlike conventional endoscopy.

Technical background

The development of transvaginal scanning (TVS) in the early 1980s had a major impact in terms of ultrasound examination of the female pelvis. It remains the principal imaging modality for assessment of the pelvic organs and associated gynaecological disorders. The diagnostic value of TVS and its major influence on clinical managements have been well documented.





The pioneering work of Smith, Craft et al (London) promoted the use of TVS in reproductive gynaecology, particularly as part of IVF and assisted reproduction techniques, from 1982 onwards. The role of TVS rapidly expanded to include major aspects of general gynaecology and early pregnancy assessments. Extensive work carried out by Smith, McMillan, Farrugia, O'Riordan et al (London) in the early 1990s focussed on the benefits of TVS specifically in the investigation of abnormal uterine (post-menopausal) bleeding. TVS became an integral part of patient investigation at hysteroscopy outpatient clinics set up by the above personnel at North Middlesex Hospital and Whipps Cross Hospital, London.

The idea of transcervical infusion of saline in order to distend the uterine cavity presented obvious advantages in terms of outlining the size and shape of the cavity and demonstrating associated pathologies. The technique of saline infusion sonohysterography (SIS), or fluid ultrasound, was established by Smith and O'Riordan within the above clinics. Ongoing work over several years at that early stage confirmed increasing favourable levels of correlation between (2D TVS) SIS and hysteroscopic findings.

The diagnostic role of TVS SIS techniques was extended with the introduction of 3D ultrasound imaging. The ability to rapidly acquire a 3D volume and easily retrieve and manipulate the stored ultrasound data has proven to be of tremendous practical value, particularly in terms of access to coronal anatomical sections through the uterus and uterine cavity. It was very quickly realised that 3D interrogation of the uterine cavity produced very precise imaging of its internal features once distended by saline. More recent advances in surface rendering techniques have further increased the diagnostic capability of SIS examination. The latest, state of the art Canon Medical Systems ultrasound systems have moved TVS 3D/4D technology on yet another step – the Aplio range provides the capability of Fly Thru virtual imaging thereby creating the true concept of ultrasound hysteroscopy.

Materials and methods

SIS is now an established procedure in many leading units. It is regarded as an integral part of TVS ultrasound and in experienced hands proves to be a relatively quick and simple technique. The whole procedure takes approx. 10–15 minutes on average which includes only a comparatively

Fig. 1a: Clinical procedure set used to carry out SIS procedures.

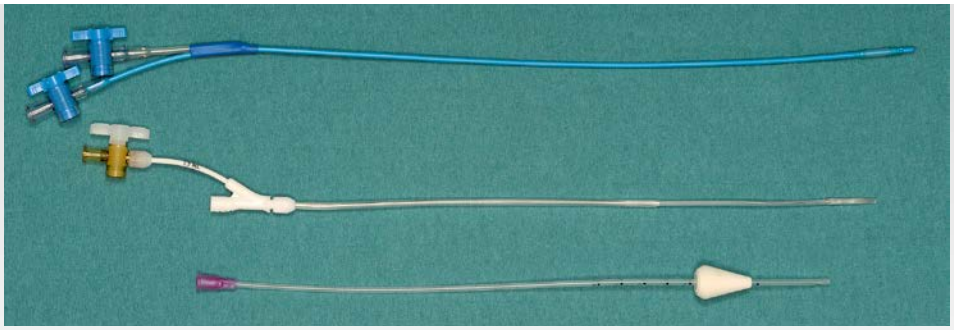


Fig. 1b: Examples of typical cannulas routinely utilised for SIS procedures.

Figs. 2: Normal uterine cavity

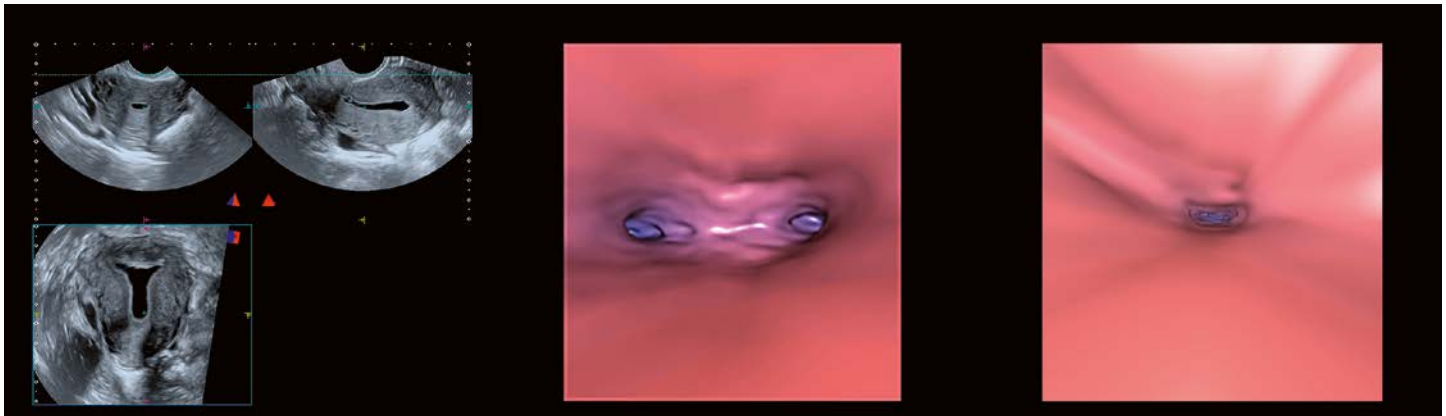


Fig. 2a **Fig. 2b** **Fig. 2c**

Fig. 2a: Multiplanar (x, y and z components) 3D SIS sections

Fig. 2b: Fly Thru imaging of the uterine cavity i.e. viewed from the cervix towards the fundal cavity and clearly demonstrating both tubal ostia.

Fig. 2c: Fly Thru imaging of the lower uterine cavity and internal os region i. e. viewed from the fundal cavity. Omnidirectional viewing of the internal features of the uterine cavity (not possible by conventional hysteroscopy) enhances anatomical and clinical information and increases diagnostic confidence.

short time involving the ultrasound imaging process itself.

A simple clinical procedure set is required (Fig. 1a) and the technique utilises some form of narrow, soft catheter. The catheter is carefully introduced transcervically using a vaginal speculum and gently inserted so the tip of the catheter lies within the cervical canal or lower uterine cavity. A seal to prevent backflow of saline is created by either inflating a small balloon (1–2 mls) or using a small cone-like device towards the tip of the cannula (Fig. 1b).

Normal saline is slowly injected and distension of the uterine cavity visualised under real time TVS control. Typically 10–20 ml of saline is required for most examinations. Injection of saline is halted at selected stages, dependent upon the degree of cavity dilatation and/or the area or structure to be examined, and a 3D volume acquisition or ultrasound sweep is carried out. The multiplanar image (Figs. 2a + 3b) obtained is reviewed and, if adequate, stored onto the system hard-drive. The procedure is then continued.

It is crucial that the 3D system functions are easy to use with very rapid acquisition, storage and retrieval of ultrasound data. In addition, it should be stressed that the image quality achieved totally reflects the basic 2D (grey scale) performance of the ultrasound system and correct utilisation of both 2D and 3D controls and presets.

On completion of the procedure, the acquired 3D ultrasound information can then be retrieved and manipulated at leisure and anatomical and clinical findings can be closely evaluated. Modern 3D ultrasound systems offer a range of image formats (Figs. 2a–c + Figs. 3a–d). These not only aid diagnosis itself but also greatly assist in terms of clinical communication and often provide valuable information in terms of pre-surgical planning.

Clinical applications

Using saline infusion technique to separate and open up the walls of the uterine cavity enables high-definition examination of its internal contour and clear delineation of intracavital lesions to be carried out. In addition, it allows detailed ultrasound evaluation of the peri-ovulatory endometrium and assessment of associated pathologies. As a result, SIS in now regarded in leading units as a routine procedure used for investigating the cause of

Figs. 3: Endometrial polyp

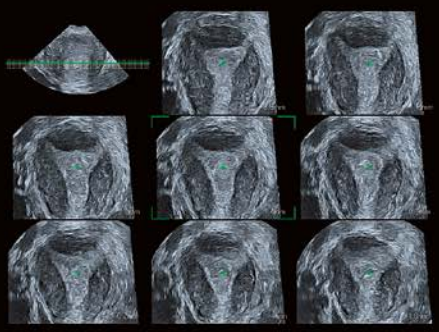


Fig. 3a

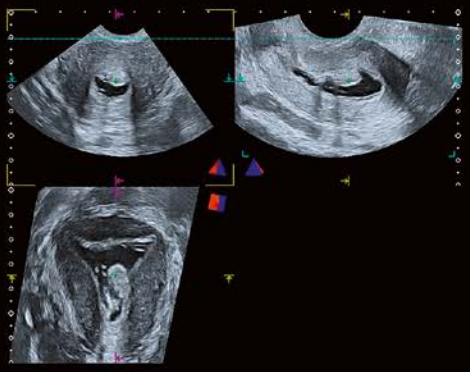


Fig. 3b

Fig. 3c

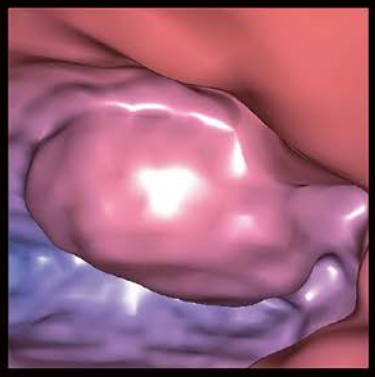


Fig. 3d

Fig. 3e

Fig. 3a: Multiview (tomographic) coronal 3D TVS sections fail to identify the polyp associated with a proliferative endometrium.

Fig. 3b: Multiplanar SIS images clearly demonstrate the lesion.

Fig. 3c: Surface rendering (SIS) in the coronal plane identifies the polyp plus associated localised thickening of the endometrium.

Fig. 3d: Fly Thru imaging of the polyp

Fig. 3e: Hysteroscopy image

abnormal uterine bleeding. It is commonly carried out where routine TVS ultrasound suggests intracavital pathology exists both in referrals presenting with atypical pv bleeding as well as asymptomatic cases. More recent clinical application involves the use of SIS as part of the preliminary investigation of female infertility. SIS is very effective in excluding or confirming the existence of relevant anatomical malformations of the uterus as well as intracavital/endometrial disorders. It is now common practice to include SIS as a pre-requisite to IVF in order to ensure the physical environment into which the resulting embryo is inserted is normal and healthy. Its clinical role extends into other areas of reproductive medicine and in major units it is now established as a key element in the investigation of recurrent miscarriage. Again, the procedure readily identifies anatomical and other gynaecological issues involving the uterine cavity and associated with increasing risk of early pregnancy failure. Fly Thru has been shown to be especially effective in excluding or demonstrating the extent of intracavital adhesions associated with evacuation procedures following miscarriage.

Ultrasound hysteroscopy: Fly Thru technology

The potential of 3D/4D TVS saline infusion sonohysterography to create an acceptable alternative to diagnostic hysteroscopy appears to be a realistic option as a result of very recent advances in Canon Medical Systems' Aplio ultrasound technology.

Fly Thru virtual imaging uses the raw data obtained from a single 3D volume data set and creates cross-sectional ultrasound imaging which produces a visual display comparable to standard endoscopy. The facility allows either manual or automatic navigation through the uterine cavity once it has been distended by saline solution. The internal contour, or any intracavital lesion present, can then be visually assessed, unlike in the case of diagnostic hysteroscopy, from any direction. The high-quality images, produced from a single 3D volume acquired by the system, provide greater anatomical detail of the internal features of the uterine cavity and improved delineation of associated lesions using Fly Thru. It confirms with greater certainty those cases which need to be referred on for surgical (endoscopic) investigation and management.

The most common cause by far of abnormal uterine bleeding, especially in post-menopausal patients, is functional in nature and invariably

Case 1: Multiple endometrial polyps

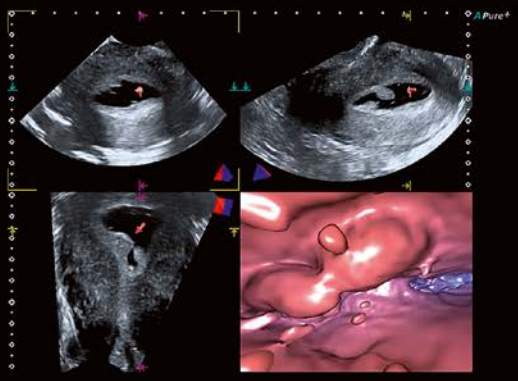


Fig. a: Multiplanar SIS + Fly Thru images of polyps

Fig. b: Hysteroscopy image

involves atypical ovarian activity. Fly Thru provides increased diagnostic confidence in excluding associated uterine pathology as the cause of abnormal pv bleeding. Conventional TVS assessment as part of the 3D technology is able to confirm dysfunctional bleeding in many of these cases.

Summary

- 3D TVS saline infusion sonohysterography is now an integral part of gynaecological ultrasound examination.
- Its diagnostic value and clinical impact in general gynaecological assessment principally involves the investigation of abnormal uterine bleeding. In addition it has a crucial role in aspects of fertility managements as well as investigation of recurrent miscarriage.
- The technical and clinical effectiveness of SIS procedure depends on the availability of modern, high-quality 3D (volumetric) ultrasound facilities.
- In leading units, SIS has replaced diagnostic hysteroscopy with considerable benefits encompassing practical, diagnostic and financial aspects as well as levels of patient acceptance.
- Advanced innovations in Canon Medical Systems ultrasound technology have resulted in the development and practical utilisation of 4D Fly Thru imaging. The visual impact and diagnostic capability it offers gives considerable credence to the concept of ultrasound hysteroscopy.

Case 2: Unicornuate uterus

Fig. a

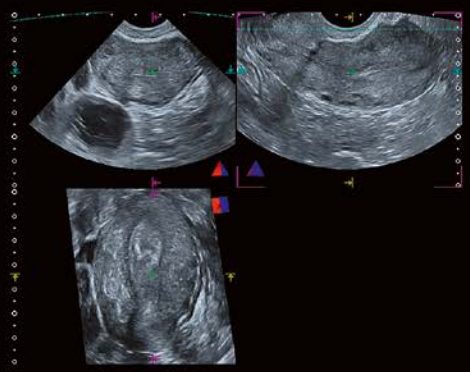


Fig. b

Fig. c

Fig. d

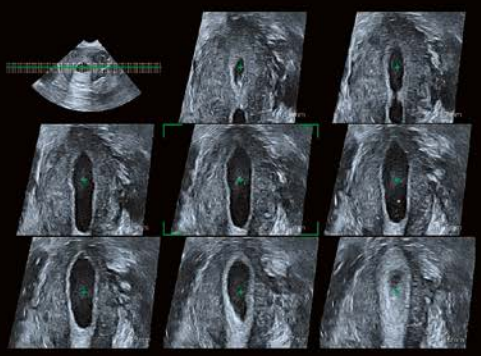


Fig. e

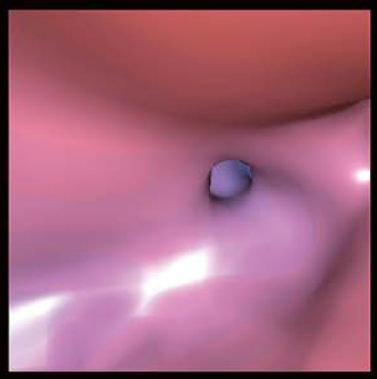


Fig. f

Fig. a: 2D (parasagittal section) TVS suggests a normal uterine cavity.

Fig. b + Fig. c: Multiplanar 3D TVS + surface rendered coronal sections respectively suggest a unicornuate uterus.

Fig. d + Fig. e: Impressions in 5b and 5c above are confirmed by 3D SIS + multiview SIS coronal sections respectively.

Fig. f: Fly Thru confirms a single tubal ostium emanating from a unicornuate cavity.

Case 3: Septate uterine cavity

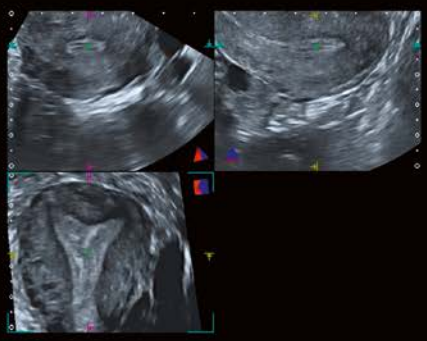


Fig. a

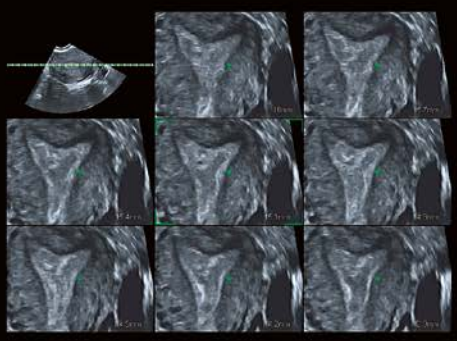


Fig. b

Fig. c

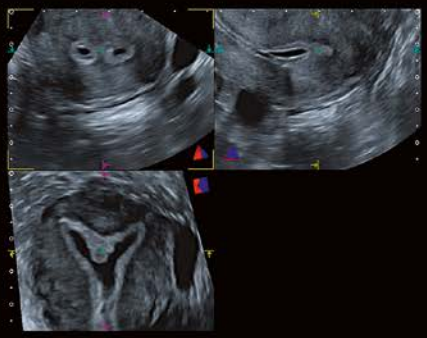


Fig. d

Fig. e

Fig. f

Fig. a + Fig. b + Fig. c: Multiplanar + multiview (coronal sections) + reconstructed 3D TVS coronal sections respectively show what appear to be a normal uterine cavity.
Fig. d + Fig. e: Multiplanar + reconstructed 3D – SIS sections clearly delineate a fibrous septum within the fundal cavity.
Fig. f: Fly Thru imaging demonstrates the septum and division of the fundal cavity with both tubal ostia visualised.

Case 4: Intracavital fibroid polyp

Fig. a

Fig. b

Fig. c

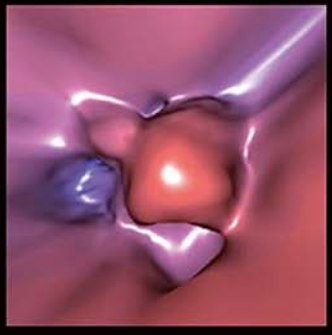


Fig. d

Fig. e

Fig. a + Fig. b: 2D TVS parasagittal section + 3D TVS reconstructed coronal rendered image (i. e. prior to saline infusion – see balloon catheter within the lower cavity) respectively show the fibroid indenting into the endometrial cavity. Fig. c: Reconstructed 3D – SIS coronal section clearly identifies the fibroid protruding into the mid-upper cavity with the balloon catheter demonstrated inferior to the lesion.
Fig. d: Fly Thru image of the fibroid polyp
Fig. e: Hysteroscopy image

Case 5: Multiple intracavital uterine adhesions

Fig. ai

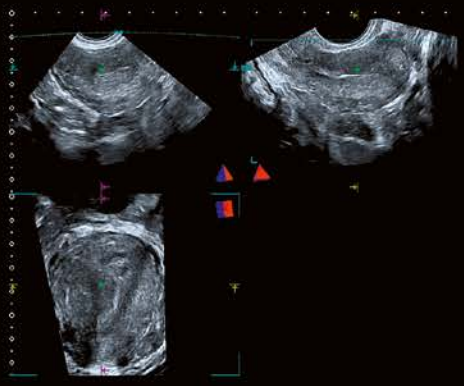


Fig. aii

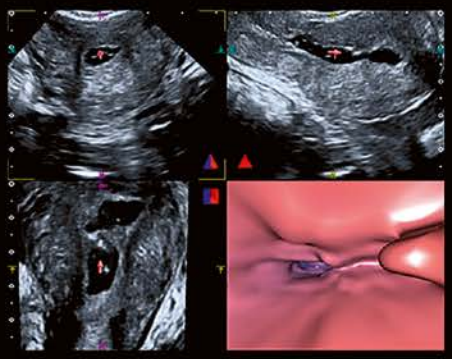


Fig. bi

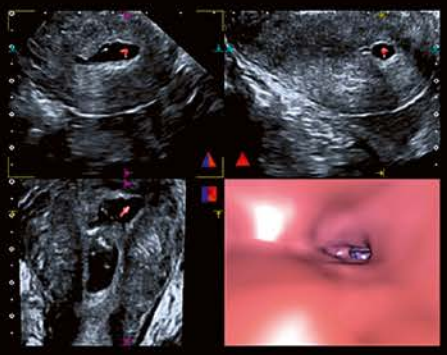


Fig. bii

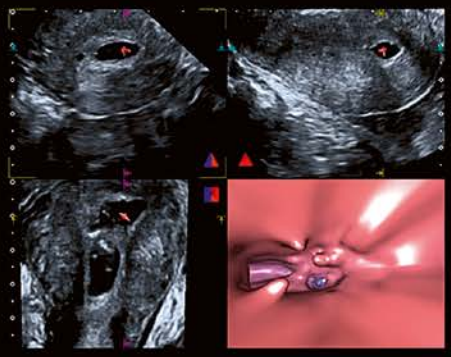


Fig. biii

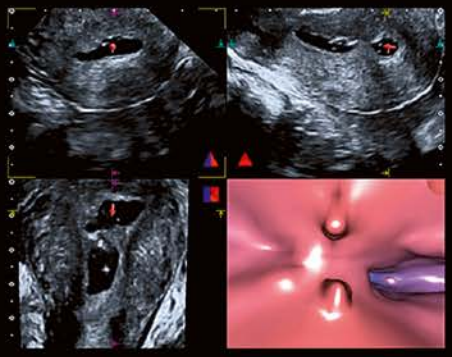


Fig. biv

Fig. bv

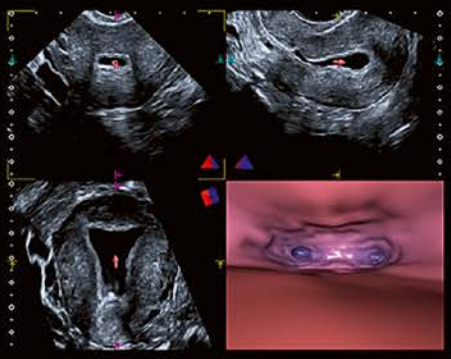


Fig. c

Fig. a i + ii: Parasagittal 2D TVS (i) + multiplanar 3D TVS (ii) sections fail to demonstrate the presence or extent of intracavital adhesions.

Fig. b i – v: Multiplanar 3D – SIS combined with Fly Thru imaging clearly outline the extent and location of multiple adhesions:

(i) mid-cavity adhesions viewed from below.

(ii) normal Lt. cornual region and tubal ostium viewed from above adhesions present within the mid-upper cavity.

(iii) multiple adhesions within the Rt. upper-cornual region of the cavity with partial occlusion of the Rt. tubal ostium.

(iv) dense adhesions within the mid-upper cavity viewed from above.

Note: Omnidirectional viewing and mapping-out of multiple adhesions prove to be of particular value in terms of pre-surgical assessment prior to hysteroscopy.

(v) Hysteroscopic image prior to resection of adhesions.

Fig. c: "Normal" uterine cavity appearances following successful resection and removal of the above adhesions.

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