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CASE REPORT

Real-time ultrasound-MRI fusion image virtual navigation for locating intraspinal tumour in a pregnant woman

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Abstract

Background Standard fluoroscopic guidance (C-arm fluoroscopy) has been routinely used for intraoperative localization of spinal level for surgical removal of intraspinal tumour, while it is not suitable for selected patients, e.g. pregnant women, who need to avoid radiation exposure. Fusion imaging of real-time ultrasound (US) and magnetic resonance imaging (MRI) is a radiation-free technique which has been reported to have good localization accuracy in managing several conditions.

Clinical presentation A 37-year-old pregnant patient, presented with a progressively aggravating lower back pain for 20 days and was incapable of lying supine with lower extremities swelling for 1 week, was referred to our hospital in her 18th week of gestation. Lumbar MRI identified an L1 level intraspinal lesion, and surgery was planned. To avoid the ionizing radiation generated by fluoroscopy, volume navigation technique (VNT) based fusion imaging of US and MRI was used to localize the intraspinal lesion, which was removed entirely via minimally invasive interlaminar approach. Pathological examination confirmed the diagnosis of ependymoma of the conus medullaris. Her symptoms were largely relieved after the operation, and a healthy baby was delivered at the 40th week of pregnancy.

Conclusion We presented the first case of using VNT based fusion imaging of real-time US/MRI to guide the surgical resection of an intraspinal tumour. Future study with larger patient number is needed to validate this technique as an alternative to fluoroscopy in patients who need to avoid radiation exposure.

Keywords MRI · Ultrasound · Volume navigation technique · Ependymoma · Pregnant · Intraspinal · Case report

Background

C-arm fluoroscopy has been routinely used for visualization of spinal structures for accurate localization of intraspinal tumours. However, like computed tomography (CT), it should be avoided in pregnant women to minimize radiation exposure to the fetus [1]. On the other hand, fusion imaging of real-time ultrasound (US) and magnetic resonance imaging (MRI) has already been used for percutaneous hepatic intervention [2], detection of prostate cancer, sacroiliac joint injections [3], etc. with good localization accuracy [4]. However, there is still no data available regarding the feasibility of applying volume navigation technique (VNT) based real-time US/MRI fusion imaging for accurate localization of the intraspinal tumours.

Clinical presentation

A 37-year-old pregnant woman who presented with progressively aggravated lower back pain and right lower limb pain for 20 days, incapable of lying supine with lower extremities swelling for 1 week, was referred to our hospital in her 18th week of gestation. She had two miscarriages and a previous caesarean delivery. Her medical record was otherwise unremarkable. The lumbar MRI at a local hospital revealed an L1 level intraspinal lesion (Fig. 1a). On admission to

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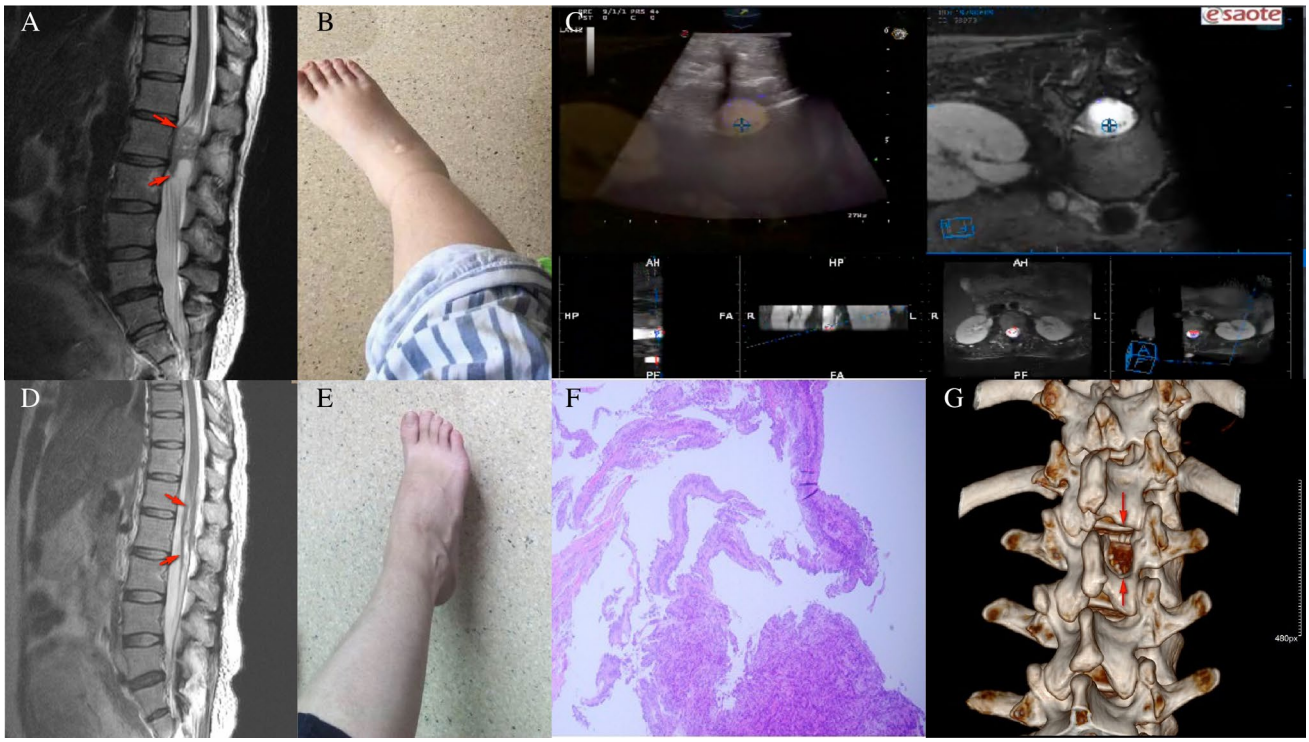

Fig. 1 Real-time ultrasound-MRI fusion imaging for accurate locating an intraspinal tumour in a pregnant patient. **a** Preoperative lumbar MRI revealed an L1 level intraspinal lesion (red arrows indicated a tumour). **b** The patient presented with severe lower extremity edema (right leg was shown). **c** Intraoperative VNT based fusion imaging of real-time US (left panel) and MRI (right panel) demonstrated the intraspinal lesion (blue cross) and accurately guided our surgical approach. **d** MRI performed 3 days after operation showed complete removal of the tumour (red arrows indicating where the tumour used to locate). **e** After surgery, lower extremity edema was completely resolved (right leg was shown). **f** Postoperative pathological examination (H&E staining) confirmed the diagnosis of ependymoma (WHO grade II). **g** After successfully delivery of the baby, three-dimensional CT volume rendering technique reconstruction of the lumbar spine showed the minimal removal of the bony structure (indicated by the area between red arrows) by our surgical approach

our hospital, she presented with forced sitting position, and neurological examination revealed normal muscle strength in her upper limbs and reduced superficial sensation below the L1 dermatome. Severe lower extremity edema was also noticed (Fig. 1b) while she was not cooperative for examination of muscle strength and tone for the lower limbs. Babinski reflex was absent on both sides.

Fusion imaging

A Mylab Twice Ultrasonography system (Esaote, Genova, Italy), capable of fusion imaging (Virtual Navigator, Esaote, Genova, Italy) and equipped with VNT platform, was coupled with a convex array transducer (1–8 MHz). After general anaesthesia, the magnetic field generator, which was located near the patient, and electromagnetic position sensor, which was mounted on the US transducer, were activated and the distance between the two was kept within 70 cm. The first step of image fusion was uploading the MRI data to the US machine. Then, image fusion between the real-time US and MRI images was achieved by both plane registration and point registration (12th rib as a bony anatomic landmark). This image registration process was repeated until optimal image fusion was obtained (the registration error between real-time US and MRI images was within 3 mm). Then real-time US and fused MRI images could be displayed side-by-side on the US monitor and move synchronously with each other (Fig. 1c).

Surgical procedure

After the induction of general anaesthesia and placement of fetal heart rate (FHR) monitoring, a left lateral decubitus position was used to avoid aortocaval compression by the fetus. A 5-cm skin incision was made in the midline centered over the L1. The interspinous ligament was kept intact, and part of the upper right L1 lamina was drilled off to expend the interlaminar space to about 1.0 × 1.5 cm in size. The ligamentum flavum was first resected piecemeal, and then the dura and the arachnoid membrane were dissected in a standard longitudinal fashion and tacked-up with sutures. A tumour, red-grey in colour, was identified and its proximal

end was found to be attached to the conus medullaris and filum terminale. After loosening of cauda equina, the thickened filum terminale the proximal tumour end was coagulated and cut off to stop tumour blood supply. To prevent the spread of tumour cells through the cerebrospinal fluid and reduce tumour size, intratumoral debulking was first performed using a cavitational ultrasonic surgical aspirator (CUSA). Some tumour sample was sent for intraoperative pathology consultation which confirmed the diagnosis of ependymoma. After debulking, the filum terminale at the distal tumour end became accessible and was cut off. Then the rest of the tumour was removed totally. The dura was closed with titanium dural clips, and the suture line was reinforced with fibrin glue to prevent epidural bleeding. The wound was closed in layers, and the operation took about 95 min with blood loss about 50 mL.

MRI performed 3 days after operation confirmed complete removal of the tumour (Fig. 1d). After surgery, symptoms such as lower extremity edema was gone the first day after surgery (Fig. 1e). She was discharged 3 days after surgery, and a healthy child was delivered via caesarean section in the 40th week of pregnancy Follow-up contrast-enhanced MRI at 15 months showed no sign of the residual tumour. The postoperative histopathological diagnosis was ependymoma (WHO grade II) (Fig. 1f). After delivery of the baby, three-dimensional CT volume rendering technique (VRT) reconstruction of the lumbar spine showed the minimal removal of the bony structure (Fig. 1g). No adjuvant radio- or chemotherapy was delivered to the patient. The patient has given her informed consent to the publication of her data. Ethical approval was obtained from the institutional ethics committee.

Discussion

C-arm fluoroscopy is the most commonly used intraoperative imaging modality during orthopedic and spinal procedures for accurate localization of spinal level. The risk to a fetus from ionizing radiation is dependent on the gestational age at the time of exposure and the dose of radiation [5]. Although there was no direct evidence showing deleterious effects on the fetus by radiation exposure from single X-ray imaging on the spine, it is the physician's responsibility to ensure this kind of risk has been minimized or, if possible, eliminated. On the other hand, MRI is the first titter diagnostic tool for intraspinal lesions, and there is no report on harmful effects on the fetus by MRI scan [6, 7]. One common technique for localization of an intraspinal tumour is by placing a water-filled balloon (external marker) on patient skin before MRI scan. However, given the mobility of the spinal column and back skin, this method is not accurate as different postures would be used during MRI examination (usually supine position) and surgical positioning (usually lateral or prone position). This inaccuracy of preoperative localization would lead to unnecessary trauma to the patient for adequate surgical exposure of the lesion. Intraoperative MRI (iMRI) could be the optimal solution for patients who need to avoid radiation exposure. However, iMRI is very expensive and is only available in a limited number of institutions. On the other hand, US is a safe, convenient, low cost, non-invasive technique that does not generate ionizing radiation. VNT has been shown to improve the sonographic spatial resolution [8–12] and would be ideal for lesions with poor sonographic conspicuity [8], such as the case of intraspinal lesions. Moreover, intraoperative US/MRI fusion imaging could be used to provide real-time feedbacks to the surgeons. There has already been a successful adoption of fusion imaging between preoperative MRI and US for brain lesion removal [13]. To the best of our knowledge, the success of our current case provided the first proof-of-concept evidence supporting VNT based US/MRI fusion imaging would be a feasible solution for intraoperative localization of MRI-detected, but sonographically ambiguous intraspinal lesions. Unlike intracranial lesions, the application of US/MRI fusion imaging for locating intraspinal lesions is more challenging for the following reasons: First, different from craniotomy where the skull is fixed, the segments of the spinal column are mobile. Second, it is more difficult to find reliable external anatomical landmarks when performing registration between MIR and US in laminotomy than craniotomy. Another alternative to current US/MRI fusion technique is simply by performing the preoperative MRI with the patient in left-sided lateral position and marking the lesion level with a clip on the skin. During the operation, a paramedian hole could be first made through the ligamentum flavum for the placement of the US-probe, which is then used for confirmation of the right surgical level before opening the dura. The advantage of this simplified US method is that it does not require VNT platform and associated software, and thus be more easily available in most surgical locations. However, similar to other MRI based skin makers, its locating accuracy is also limited by the mobility of the spinal column and skin. Moreover, additional trauma would occur if multiple level fenestrations of the ligamentum flavum were needed due to locating inaccuracy.

After consultation with the anaesthesiologist and gynecologist, precautions like left lateral decubitus position [14], appropriate anesthesia method, and FHR monitoring were taken for the better protection of the fetus during surgery. The operation is fast and satisfactory clinical outcomes were achieved. After successful delivering the baby, postoperative CT-VRT reconstruction of lumbar spine confirmed minimal removal of the bony structure, and thus might contribute to quicker recovery and better preservation of patient's spinal stability [15]. However, this technique

also has some inherent difficulties like its reliance on manual guidance and experienced sonographer. Meticulous evaluation of radiological discordances between US and MRI should be performed to ensure the optimal performance of this technique. Development of more user-friendly software would be beneficial for its adoption by relevant surgeons, e.g. neurosurgeons and spine surgeons, by shortening their learning curve [16]. Future acceptance of this novel technique as a reliable alternative to C-arm fluoroscopy for the localization of intraspinal lesions in selected patients will depend on the evaluation of its efficacy in a larger number of patients.

Conclusion

VNT based fusion imaging of real-time US and MRI allows us to accurately localize an intraspinal tumour in a patient who needs to avoid ionizing radiation from conventional fluoroscopy.

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Author contributions TJL and FS conceived and wrote the manuscript. CZ and PTH did data collection and contributed to manuscript writing. YJZ did the review and final approval of the manuscript.

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Compliance with ethical standards

Ethical statement The patient has given her informed consent to the publication of her data. Ethical approval was obtained from the Ethics Committee of Second Affiliated Hospital of Zhejiang University School of Medicine.

Conflict of interest The authors declare that they have no conflict of interest.

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