SHORT REPORT

Non-invasive assessment of extracranial–intracranial bypass grafts using advanced ultrasound technology

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There have been significant developments in ultrasound technology in the last few years which have resulted in an increase in the clinical value of this technique. An illustrative case is presented of how ultrasound technology has been used in the intraoperative and postoperative period to evaluate graft patency and function in patients undergoing extracranial–intracranial bypass graft surgery.

Extracranial–intracranial (EC–IC) bypass grafting is an effective surgical treatment for the management of selected cases of intracranial aneurysmal disease that would not be amenable to surgical clipping or endovascular occlusion.^{1–4} Catheter angiography is traditionally used for the perioperative assessment of graft function and patency. This type of imaging has various disadvantages. Catheter angiography is invasive and carries a finite morbidity, a consideration that is particularly important in patients who have undergone a neurovascular surgical procedure which is itself associated with morbidity. This factor becomes increasingly significant if repeated radiological assessment of graft function is necessary. Furthermore, the use of intraoperative angiography is limited by the difficulty in achieving adequate radiographic projection and angiographic quality in the operating theatre.

We describe the use of intraoperative and postoperative ultrasound for the assessment of graft patency and function. This imaging strategy provides an alternative approach to catheter angiography for the radiological assessment of EC–IC bypass.

CASE REPORT

A 50 year old woman presented with a four month history of right sided worsening ophthalmoparesis. There was no history suggesting subarachnoid haemorrhage. On examination she had a Glasgow coma score of 15. The right third, fourth, and sixth cranial nerves and the first and second divisions of the trigeminal nerve were impaired. Computed tomography (CT) showed an enhancing lesion at the level of the right cavernous sinus which catheter angiography confirmed to be a 2 cm diameter intracavernous sinus aneurysm. The patient also underwent a balloon occlusion test which was clinically tolerated very well. A SPECT scan performed before and during the occlusion did not show any alteration of cerebral blood flow on the right.

In consideration of the young age of the patient and the risks of cerebrovascular ischaemia associated with isolated vessel occlusion, an EC–IC bypass was offered.

Under barbiturate EEG guidance and mild hypothermia (35°C), a right internal carotid M2/M3 saphenous venous bypass was undertaken. During the procedure, trapping of the aneurysm was also accomplished.

After completion of the bypass, patency of the graft was confirmed by ultrasound using a GE Logiq 700 scanner and a 10 MHz linear probe (GE Medical Systems, Milwaukee, Wisconsin, USA). Flow was demonstrated within the extracranial and intracranial components of the graft. The patient made an excellent postoperative recovery with resolution of the ophthalmoplegia.

Follow up ultrasound was performed in the postoperative phase. Graft patency was again confirmed, and the flow velocity within the graft was measured at 46 cm/s (fig 1). Examination of the anastomosis site was undertaken with colour flow Doppler, and flow from the graft into the M2 anastomosis could clearly be seen (fig 2). Excellent filling of the M3

Figure 1 Triplex ultrasound shows excellent flow within the subcutaneous component of the graft. Peak systolic velocity is measured at 46 cm/s.

Figure 2 Duplex ultrasound demonstrating flow at the graft–M2 anastomosis.

Figure 3 Duplex ultrasound shows excellent filling of the M2 and M3 branches.

Figure 4 Catheter angiogram confirms graft patency and flow into the M2 and M3 vessels.

branches was also demonstrated (fig 3). These findings were confirmed with catheter angiography (fig 4).

DISCUSSION

EC-IC bypass grafting can be an effective method for the treatment of selected cases of intracranial aneurysm that are otherwise not suitable for direct surgical clipping or endovascular embolisation.¹⁻⁴ Catheter angiography is the traditional standard of reference for the follow up of such patients in the postoperative period, and is also used for the perioperative confirmation of graft patency.⁵ Catheter angiography is, however, associated with significant problems. It is an invasive procedure and carries a well defined morbidity relating to neck vessel dissection and intracranial thromboembolic complications, as well as local femoral artery trauma. Bypass surgery is itself a high risk procedure and any additional risk associated with the investigation of these patients should be minimised. In addition, catheter angiography is a time and cost intensive procedure, and is associated with a significant dose of ionising radiation. Furthermore, its intraoperative use is limited by the physical difficulties involved in undertaking angiography in the neurosurgical operating theatre.

There is therefore a need for a non-invasive imaging strategy that allows assessment of graft patency and intracranial graft function. Ultrasound has been applied to imaging EC-IC grafts in the past,⁶⁻⁸ but its more widespread acceptance

has been restricted until recently by specific technical limitations. However, rapid developments in ultrasound technology have dramatically improved the efficacy of the technique, resulting in a decreased reliance on catheter angiography for the investigation of intracranial and extracranial vascular diseases. However, little has been published on the application of this improved technology to the investigation of EC-IC bypass procedures.

Ultrasound was suggested as a means for the non-invasive investigation of bypass grafts in the early 1980s, and there are several reports describing the value of Doppler ultrasound for demonstrating graft patency or occlusion. The technology was limited at that stage to Doppler assessment of flow velocities and waveforms, and did not provide real time images of sufficient quality. In addition, the intracranial component of the graft could not be consistently evaluated with Doppler ultrasound, further limiting its usefulness in the assessment of EC-IC grafts. There have, however, been major advances in ultrasound technology, including the development of colour flow imaging and high resolution triplex imaging. These advances have recently been further enhanced by the development of digitally encoded ultrasound and digitally enhanced imaging, resulting in a vastly improved efficacy in the imaging of a variety of vascular disorders.

In this report we illustrate the effectiveness of advanced ultrasound technology in the imaging of EC-IC grafts. The patency of the extracranial and intracranial components of the graft can readily be demonstrated. In addition, the intracranial anastomosis can be clearly visualised, and dynamic flow across the anastomosis shown. The flow velocity within the graft can easily be measured, and we speculate that this measurement may have prognostic value in predicting the long term patency of the graft. Anecdotally, we have observed one case in which flow velocity of less than 20 cm/s was associated with subsequent graft failure.

Ultrasound examination is inexpensive and relatively rapid, and provides intuitive haemodynamic information. Furthermore, as this report shows, it is readily transferable to the operating theatre, and it is relatively easy to integrate intraoperative ultrasound examination with the surgical procedure. This facility has also been reported recently by Badie *et al.*⁹ It is, however, operator dependent, and experience with the use of the technique is required.

Other non-invasive imaging techniques have been applied to the investigation of patients with EC-IC bypass. Magnetic resonance angiography is effective in demonstrating graft patency and morphology¹⁰ postoperatively, and is used at our institution for this purpose. However, it does not generally provide information on flow velocity or on the dynamics of graft function. CT angiography similarly demonstrates the vascular anatomy without assessing dynamic flow within the graft and has the additional disadvantages of requiring contrast administration and of having a significant associated radiation dose. By comparison, ultrasound provides information on flow dynamics within the graft, as well as morphological imaging.

Ultrasound has several advantages as a technique for the evaluation of EC-IC bypass grafts. It is non-invasive and relatively inexpensive, and is readily transferable to the operating theatre. It can be used to assess graft patency and function, and can evaluate the flow dynamics within the graft. The measurement of flow velocity within the graft may have prognostic importance for long term graft patency, and we are in the process of acquiring such data prospectively. Consequently, ultrasound is routinely used at our institution in the evaluation of patients undergoing EC-IC bypass graft surgery.

Ultrasound can reduce the requirement for catheter angiography in the follow up of these patients, as well as providing additional information on flow dynamics. We recommend the use of advanced ultrasound technology for the follow up of graft patency and function in patients undergoing EC-IC bypass procedures.

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NEUROLOGICAL STAMP.....

Harvey Williams Cushing (1869–1939)

Sir William Macewen (1848–1924) of Glasgow was the first practitioner of modern neurosurgery, but he didn't devote the majority of his time and energy to this field. In 1888 he published his report on 21 operations with 18 recoveries, thus demonstrating the possibility of operating safely on the brain. In 1886, Victor Horsley (1857–1916) was appointed surgeon to the National Hospital for the Paralysed and Epileptic at Queen Square, London. This was the first neurosurgical appointment anywhere. In the first year of his appointment he performed 10 cranial operations. Horsley operated only by invitation. He had no beds of his own, no surgical service and no laboratories.

One of the most important figures in the early development of neurosurgery was Harvey Cushing who arrived at The Johns Hopkins Hospital and Medical School in the autumn of 1896 as William Stewart Halstead's assistant resident in surgery. Cushing subsequently worked out an arrangement with Halstead whereby he handled the neurological cases. By 1904 when he delivered a paper before the Cleveland Academy of Medicine on *The Special Field of Neurological Surgery* his enthusiasm for the field was well established. During his surgical residency at Johns Hopkins he learnt the delicate handling of tissue in the Halstead tradition. Cushing was largely responsible for neurosurgery being recognised as a distinct entity. Important technological advances, such as the discovery in 1895 of x rays by Roentgen, Walter Dandy's invention in 1918 of air encephalography and, in 1919, pneumoencephalography, assisted the development of the speciality. Dandy, with whom Cushing had a strained relationship, was his assistant resident from 1911–12.

Cushing's first article described the case of a gunshot wound to the cervical spine. In the paper was a reproduction of an x ray he had taken himself, which showed the bullet in the

spinal canal. He pioneered several important techniques in neurosurgery, relating especially to the control of blood pressure and haemorrhage during surgery, the improved understanding of raised intracranial pressure, and the natural history and pathology of lesions of the central nervous system. His research on brain stem control of systemic blood pressure during raised intracranial pressure lead to what is known as the *Cushing Response*. In 1901 he assisted Charles Sherrington in mapping the motor cortices of anthropoid apes. Cushing identified several varieties of brain tumours and made great advances in their treatment. He also made substantial contributions to understanding of the separate functions of the anterior and posterior lobes of the pituitary, and was the first to associate pituitary adenoma with *Cushing's syndrome*. Following his suggestion in 1919, the Society of Neurological Surgeons was formed. By 1930 the society had become

very restricted in its membership. In 1931, with Cushing's permission, the *Harvey Cushing Society* was formed by a group of young neurosurgeons.

As a soldier during World War I, he designed a base hospital that could be mobilised at short notice. He had a lifelong interest in the history of medicine. Halstead was the first professor of surgery at Johns Hopkins, but, professionally, Cushing's most important friendship was with Osler. His *Life of Sir William Osler* won him the Pulitzer Prize in 1926. During his career, Cushing published 13 books and 300 scientific articles. His large collection of books and papers was donated to the Yale medical Library, which he helped to plan. The destroyer USS Cushing launched on 31 December 1935, and completed on 10 December 1936, was named in his honour.

Cushing was honoured philatelically on a stamp issued by the United States in the series honouring Great Americans. The first day of issue of the Harvey Cushing stamp was 17 June 1988 (Stanley Gibbons 2129, Scott 2188).

L F Haas

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