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USEFULNESS OF AN INTEGRATED HYBRID SUITE IN CRANIAL NEUROSURGERY.

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ABSTRACT

The integrated hybrid suite combines a traditional operating theatre with an image guided interventional suite, allowing for highly complex, advanced neurosurgical procedures to be performed efficiently and safely. The first generation hybrid operating suite, consist of an angiography table in the operating theatre, which only allows for real-time fluoroscopic imaging to be carried out. The second generation integrated hybrid suite maximises the use of intraoperative dynamic imaging and with software advancement, allows for complex imaging such as cone-beam computed tomography to be conducted without having the patient leaving the operating table or operating suite. We describe our early experience with using a second generation advance integrated hybrid suite system equipped with a robotic angiographic fluoroscopy system in performing complex neurosurgical cases and discussed the advantages of having such a system in any surgical department.

Keywords: Angiography, digital subtraction, Cerebrovascular disorders, diagnostic imaging, Cone-beam computed tomography, Neurosurgical procedures, Operating rooms, integrated hybrid suite.

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Keywords: Angiography, digital subtraction, Cerebrovascular disorders, diagnostic imaging, Cone-beam computed tomography, Neurosurgical procedures, Operating rooms, integrated hybrid suite.

INTRODUCTION

The integrated hybrid suite (IHS) is an advanced operating layout, which combines a traditional operating theatre with an image guided interventional suite. This allows highly complex, advanced surgical procedures to be performed, as well as, safe and efficient transitions between open and minimal invasive (including endovascular) procedures in both cranial and spinal surgery. Current second generation IHS maximises the use of intraoperative dynamic imaging and with software advancement, allows for complex imaging such as cone-beam computed tomography to be conducted without having the patient leaving the operating table or operating suite. Hence allowing for safe conduct of complex surgeries with confirmation of satisfactory result before the patients leave the operating room. We described our early experience with using an IHS system equipped with a robotic angiographic fluoroscopy system in conducting

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three neurosurgical cases as a reflection of the usefulness of such system in performing complex surgery.

CASE REPORTS

Stereotactic biopsy of pontine lesion

A 35 year old male with a history of recreational intravenous drug use, presented with acute onset of dizziness and unsteady gait. On examination, he was noted to have diplopia, left dysmetria and nystagmus. Contrasted computed tomography (CT) and magnetic resonance imaging (MRI) of the brain demonstrated a 1.3 cm x 1.2 cm left hemipons peripherally-enhancing lesion with extension into the left middle cerebellar peduncle associated with perilesional oedema (Figure 1A). There were no other cranial lesions present. The patient was counselled and underwent a stereotactic biopsy of the pontine lesion via a left transcerebellar transpeduncular route under neuro-navigation in the IHS. An intraoperative CT brain was performed following the biopsy of lesion (Figure 1B). This was to ascertain that there were no acute neurosurgical complications, such as a haematoma, that will preclude a safe extubation and the intended target was sampled. The patient was extubated safely and he was treated medically for toxoplasmosis. The histology revealed chronic inflammatory cells.

Comment: Procedural-related complications to the brainstem may be insidious and difficult to assess in a patient under general anaesthesia. The ability to perform intraoperative CT brain was important in this case to ascertain the safety of anaesthetic reversal. It was also useful to be able to confirm that the target lesion was sampled.

Resection of cavernoma

A 63 year old male presented with acute onset of headache and right sided hemiparesis. CT brain showed a left basal ganglia bleed and an incidental heterogenously dense lesion in the right inferior parietal lobe. MRI brain subsequently confirmed a cavernoma located at the inferior portion of the right pre- and post-central gyrus, anterior to the supramarginal gyrus (Figure 2A-B). The cavernoma was associated with a developmental venous anomaly (DVA) and had evidence of previous bleed. A cerebral angiogram was performed to further characterise the DVA

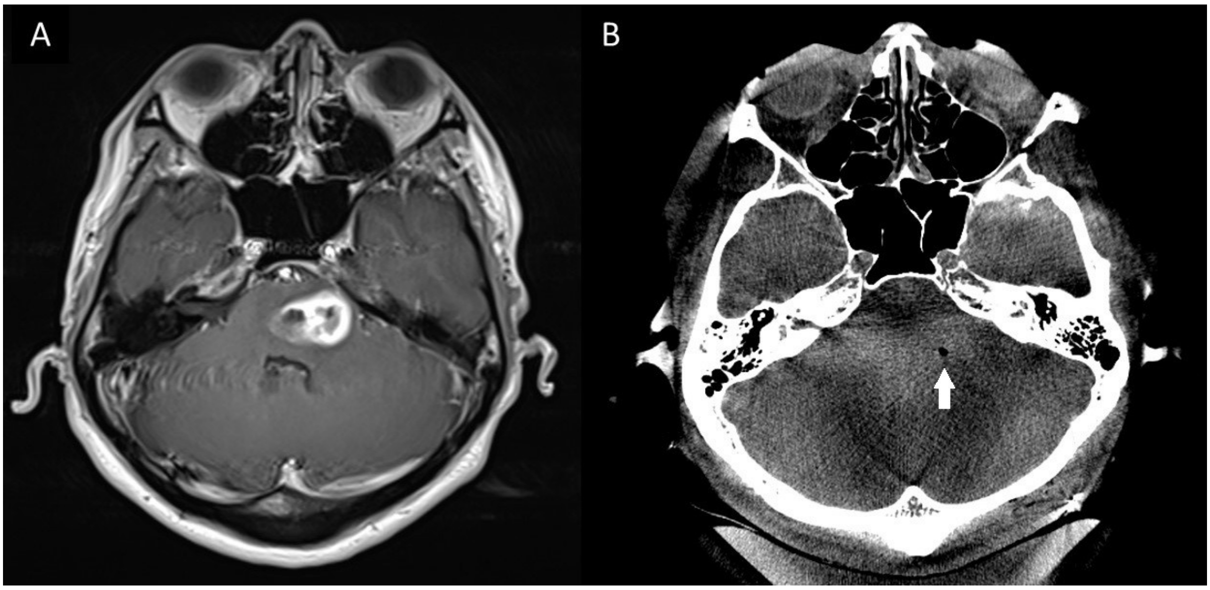

Figure 1: (A) MRI brain demonstrating a left hemipons peripherally-enhancing lesion; (B) intraoperative cone-beam CT demonstrating no iatrogenic haematoma and pneumocephalus (white arrow) at biopsy site.

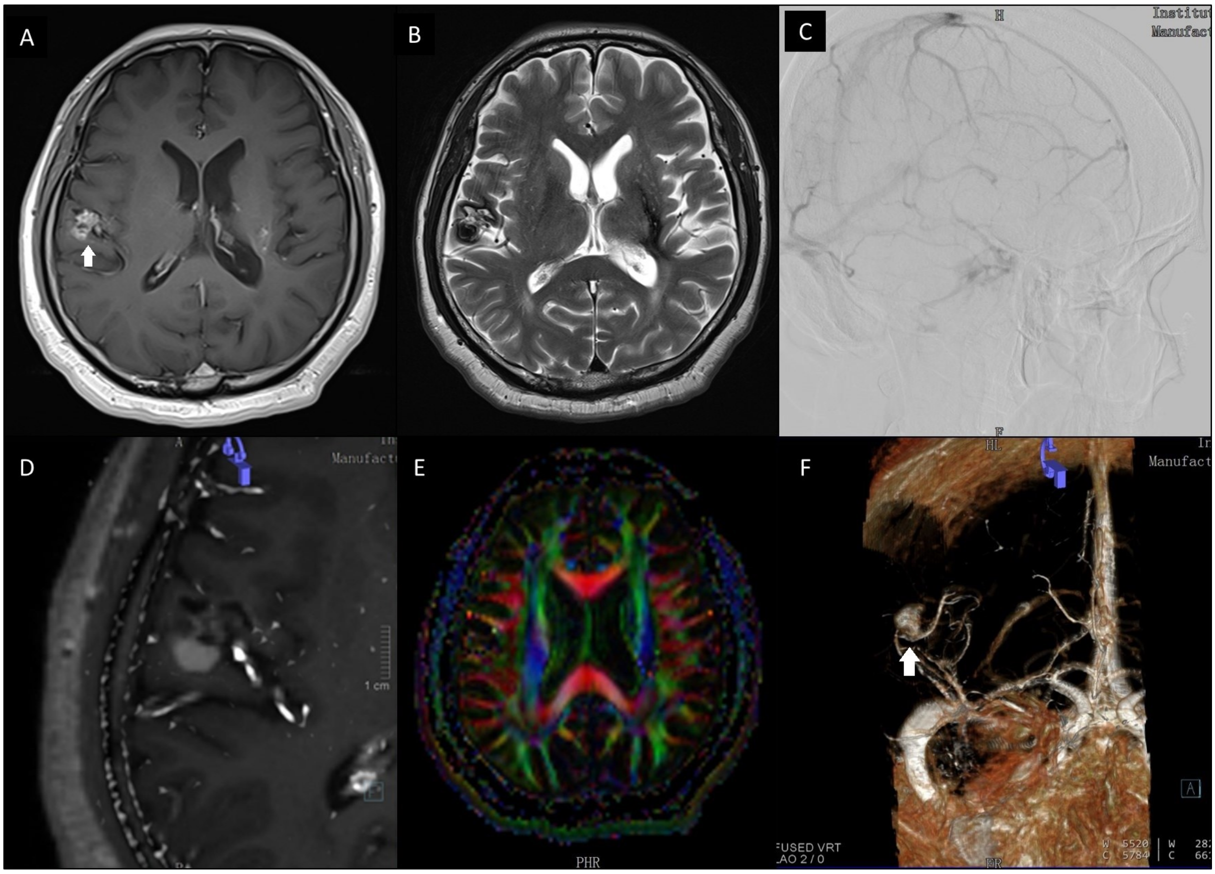

Figure 2: (A-B) MRI brain demonstrating the right parietal cavernoma (white arrow); (C) cerebral angiogram to assess the normal venous drainage; (D-E) intraoperative fusion of MRI with cerebral angiogram (D), DTI (E) and digital subtraction of brain parenchyma (F) for surgical planning and neuronavigation of cavernoma and developmental venous anomaly (white arrow).

and surrounding vasculature (Figure 2C). Given the patient's residual right sided weakness from the previous left basal ganglia bleed, any further neurological deficits resulting from the cavernoma rebleed can significantly affect his overall function and quality of life. Therefore, the patient was counselled for an elective resection of the right parietal cavernoma following recovery from his left basal ganglia bleed. The surgery was performed under neuronavigation guidance using a combination of MRI, cerebral angiogram and diffusion tensor imaging (DTI) to ensure resection of the cavernoma while preserving the DVA (which usually drains normal brain) and minimising disruption to normal white matter tracts, respectively (Figure 2D-F). The patient had an uneventful postoperative course with no new neurological deficits.

Comment: the planning module for navigation in the IHS allowed for the fusion of the different brain imaging modalities (MRI, cerebral angiogram, DTI) to visualise the cavernoma and the important surrounding structures intraoperatively. The optimum surgical corridor can be determined and safe resection of the cavernoma could be performed.

Resection of arteriovenous malformation

A 36 year old male presented with first onset generalized seizure, with subsequent permanent right hemianaesthesia. A non-contrast CT brain demonstrated no acute detectable haemorrhage but irregular hypodensities in the left posterior parietal lobe with serpigineous vessels. Contrasted MRI brain confirmed the presence of an arteriovenous malformation (AVM) over the left superior parietal lobe, posterior to the post-central gyrus

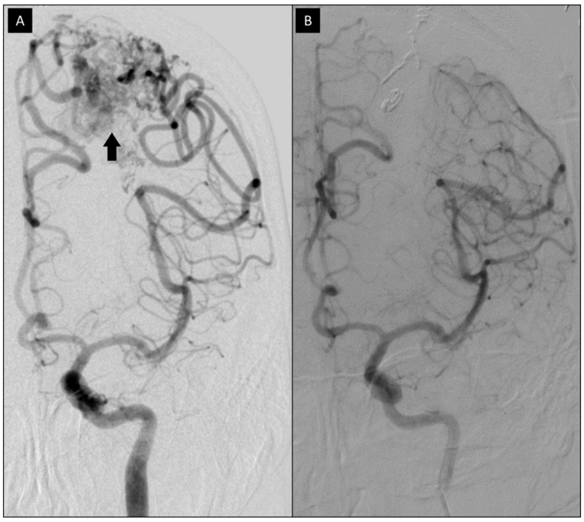

Figure 3: (A) cerebral angiogram demonstrating the left parietal AVM (black arrow); (B) intraoperative cerebral angiogram demonstrating complete resection of the AVM. (Click on image to enlarge)

and superior to the supramarginal and angular gyri. There was also evidence of a small bleed at the inferior aspect of the AVM. Functional MRI and DTI demonstrated that the AVM does not involve the functional regions of the brain and cortical-spinal tracts respectively. A cerebral angiogram was performed which demonstrated a 3.5 cm AVM nidus, with the main arterial feeders from the middle cerebral artery, and supplementary arterial feeders from the anterior cerebral artery and posterior cerebral artery (Figure 3A). The draining vein empties superficially through distended cortical veins towards the superior sagittal sinus. He underwent an elective resection of a left parietal AVM. An immediate intraoperative cerebral angiogram was conducted in the IHS, confirming complete occlusion and resection of the AVM (Figure 3B). The patient made an uneventful postoperative recovery with no new neurological impairments.

Comment: the IHS enabled the performance of an intraoperative cerebral angiogram post resection of an AVM. This reduces the need for transfer of intubated patients which improves patient safety and decreases operative time. Real time updates in the IHS also enable adequate radiological assessment of the AVM vasculature by the surgical team to help ensure complete resection has been achieved.

DISCUSSION

Intraoperative technology, ranging from neuro-navigation to imaging systems, plays a significant role in neurosurgery.[1] Since its introduction in the 1990s, the concept of hybrid operating room and its adoption has been increasing. This facility in Pantai Jerudong Specialist Centre was established in 2017. In general, an IHS comprises of a multi-axis robotic C-arm, a specialised boom mount for the display panel to increase mobility, and use of a radiolucent operating tabletop with attachments for the headrest or radiolucent head clamp system (Figure 4). This allows for the performance of combined open and endovascular neurosurgical procedures in one location. Recent advancements in software have also allowed for the performance of intraoperative cone-beam CT (CBCT) using the robotic angiographic fluoroscopy system by performing a 360 degrees rotational acquisition of the subject.

The amalgamation of such technologies into a singular space enables complex surgical procedures to be performed with improved patient safety and surgical efficiency by allowing for seamless transition from surgical to angiographic positions as demonstrated above. In the stereotactic biopsy of pontine lesion and AVM resection cases, the patients would otherwise had to be transferred from the operating theatre to the radiology department for CT brain and cerebral angiography, respectively before planning the next course of management. Treatment plans can now be revised and procedures requiring multiple interventions or modalities can be performed in the same surgical suite in a single session.[2] Importantly, the IHS is also easily adaptable to allow for standalone standard neurosurgical (cranial and spinal) and endo-

Figure 4: The integrated hybrid suite system equipped with a multi-axis robotic C-arm (A), radiolucent tabletop operating table (B) and a specialised boom mount for the display panel (C).

vascular procedures without compromising on workflow and ergonomics of these procedures.

Several studies have shown the feasibility, safety and impact of the IHS in the treatment of cerebrovascular conditions.[3-8] Choi *et al.* showed that a hybrid operating theatre with a high-end digital subtraction angiography (DSA) system provided safe and precise treatment for neurovascular disease with intraoperative angiography, combined endovascular and surgical procedure, or complementary rescue procedure of intervention and surgery in a single session.[9] Intraoperative angiography revealed unsatisfactory clipping of intracranial aneurysms and remnant AVMs which resulted in further clip reposition, and complete AVM removal in the same surgical session. In spinal neurosurgery, Murayama *et al.* reported the usefulness of the intraoperative robotic DSA in providing safe and precise treatment in neurosurgery, including spinal instrumentation.[10]

In comparison to the first generation hybrid operating suite, which was simply an angiography table in the operating theatre, the second generation IHS maximises the use of intraoperative dynamic imaging and minimises the limitations of patient positioning. With the use of the CBCT (CT obtained with the rotating C-arm), real-time images can be obtained so that surgical guidance can be based on ”live” intraoperative images which takes into account brain shift, changes in ventricular size and unexpected bleeding. In spine surgery, the changes in spine alignment due to patient positioning can be re-evaluated and image-guided instrumentations can be performed more accurately and safely.[11] In addition, this development avoids the need for a conventional intraoperative CT scanner, which can cumbersome and inflexible, and limited to a single imaging modality.

There are some disadvantages to the IHS. Radiation exposure remains a concern.[12] Scatter radiation to surgeons, nurses, anaesthetists and other operating theatre personnel must be monitored and essential steps must be taken to minimise radiation exposure to staff.[13] Shielding with appropriate lead shields such as lead aprons, goggles and thyroid shields is compulsory and low dose protocols should be used when possible to reduce scatter radiation. During the performance of 3-dimensional angiography and CBCT, non-essential staff should not be within the radiation zone of the operating theatre. The biplane angiographic system remains the gold-standard for neurointerventional procedures. Therefore, close cooperation between the neurosurgeon and neurointerventionist is important to determine appropriate treatment strategies for patients in the IHS, where only uniplanar angiography can be performed.

CONCLUSION

The integrated hybrid suite is an important technological advance in neurosurgery. Integrations and combinations of different treatment and imaging modalities is an essential step towards improving the safety and efficacy of surgical procedures.

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CONFLICT OF INTEREST

The author(s) declared no conflict of interest in this work.

CONSENT

Consent has been obtained from patients and hospital authority to publish this article.

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