Adapting Electromagnetic Navigation System for Transoral Robotic Assisted Skull Base Surgery

Short Title: TORS with Navigation

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Introduction

Transoral robotic surgery (TORS) has been established as a safe and effective minimally invasive surgical technique, especially in managing early cancers of the oropharynx[1]. Early on in the development of (TORS), experiments on the applying TORS for surgery to the skull base, including the parapharyngeal space and nasopharynx had been conducted in cadavers and later translated to clinical use [2-4].

Image guided surgery (IGS) utilizing surgical navigation systems are widely used in endoscopic endonasal operations of the anterior skull base. Use of navigation improves the safety of the operation by enabling the surgeon confidently identify the anatomy and pathology. This especially important in a minimally invasive approach where the surgeon can easily be disoriented and the anatomy distorted by the pathology [5,6].

Unfortunately simultaneous deployment of the surgical robot and navigation system still poses a challenge in the operation room. After deployment of the robot, there would be lack of space to deploy the navigation system. The robot arms may block the line of sight of the optical sensors of the optical navigation system to the reference post place on the patient’s head. Moreover, the robotic arms may accidentally displace the reference post without the surgeon’s aware.

The new generation of surgical navigation systems using electromagnetic (EM) fields for navigation does not require the a line of sight of the reference post to the sensor. Also, the EM field sensor of the navigation system is now placed on the head rest of the operating table, directly below the patient’s head, minimizing the interference from ferromagnetic surgical instruments placed adjacent to the operative site. We describe our technique of adapting the a EM navigation system to be used during TORS.

Materials and Methods/Results

There were total of four cases. Three cases were robotic nasopharyngectomy, with two cases of recurrent nasopharyngeal carcinoma and one case of benign harmatoma of the Eustachian tube. The last case was a minor salivary gland tumor in the right pre-styloid parapharyngeal space. All operations were performed with the da Vinci Xi surgical robot (Intuitive Surgical Inc., Sunnyvale, CA). The navigation system employed was the Fiagon Tracey Navigation System (Fiagon GmBH, Hennigsdorf, Germany). A 0.5mm axial arterial phase contrast computer tomography scan (CT scan) of the head was performed on the morning of the operation and transferred to the navigation system. Bone window of the scans was employed and adjusted until the major arteries were visible.

All operations were performed under general anesthesia with oral intubation by an oral Rae tube. The head plate of the operation table was replaced by the dedicated EM sensor of the navigation system, according to the operating manual of the system. The patient localizer of the navigation system was placed over the forehead with self-adhesive tapes. Surface registration technique was employed and the surgeon confirmed the accuracy of the navigation with bony landmarks on the facial skeleton before docking of the robot. The video output of the navigation system was connected into the vision cart of the surgical robot for simultaneous visualization in the surgeon's console using the TilePro™ function of the da Vinci Xi robot.

A Dingman retracted was employed to open the mouth and secured in position with an endoscopic holder (Karl Storz, Tuttlingen, Germany) fixed to the surgical table. Surgical techniques of the robotic nasopharyngectomies and parapharyngeal space tumor resection were identical to the techniques previously described. Below are the description of the robotic IGS in nasopharynx and parapharyngeal space, with reference to identification of major vascular structure and tumor boundaries.

TORS Nasopharyngectomies

The main application of the navigation system in TORS nasopharyngecomies is the identification of the internal carotid artery (ICA). After initial dissection of the lower part of the nasopharynx, the position of the ICA in the parapharyngeal space was ascertained by the navigation system. It is usually the bedside surgeon the apply the probe of the navigation system to the surgical field for localization of the anatomy (Figure 1). To reduce any interference to the magnetic field by the ferromagnetic robotic arms, the arms were retracted a few centimeters so that the robotic arms were more distal than the probe to the EM sensor in the head plate of the operating table. The console surgeon then switched on the TilePro™ function for simultaneous visualization of the endoscopic view of the nasopharynx and the navigation scans. Figure 2 shows the screen capture of the robotic console during simultaneous view of the endoscopic view and navigation scans while the navigation probe was placed in the surgical field. There was no need to undock any robotic arms during the use of navigation system. After ascertaining the location of the ICA, the console surgeon could then decide on where exactly to place the lateral and posterior limit of the dissection with confidence that the resection would not injure or expose the ICA. In the case of the harmatoma of the Eustachian tube cartilage, the navigation system did helped the surgeon to ensure he had reached the posterior limit of the tumor (Figure 3).

TORS Excision of Parapharyngeal Schwannoma

This was a parapharyngeal minor salivary gland tumor that pushed the internal carotid artery posteriolaterally. The operative procedure was similar to other surgeons' technique described in the literature. After completion of the resection, the surgical field was inspected. An area of pulsation over the posteriolateral part of the surgical field was identified. The navigation probe was then used to point to the area and found to be 1-2mm anterior to the ICA. Blunt dissection of the muscles in the area then revealed a pulsating vessel, confirmed to be the ICA with the navigation probe (Figure 4). To further ascertain that the structure was indeed the ICA, 5ml of 0.5% indocyananin green (ICG) was given intravenously and the Firefly^{TM} function of the da Vinci robot was engaged. Strong florescence of the structure few seconds after injection of the ICG confirmed that the structure was indeed an artery, the internal carotid artery (Figure 5).

Discussions

The application of surgical navigation system in endoscopic sinus surgeries and skull base surgeries have not just improved the safety of the operation and also ensured completeness of the operation. The American Academy of Otolaryngology – Head and Neck Surgery stated in a the Position Paper on Intra-Operative Use of Computer Aided Surgery that IGS is indicated in cases where disease abuts the skull base, orbit, optic nerve or carotid artery [7]. In our center, we have been using IGS during endoscopic nasopharyngectomies but not robotic nasopharyngectomies as we had difficulties in deploying our previous generation of optical navigation system simultaneously with the da Vinci Robot. In order to use the optical navigation system during robotic surgery, the robotic arms needed to be completely removed from the oral cavity and place away from the head so that they will not block the line of sight of the optical sensors to the reference post. Desai et al. had described adapting an optical navigation system for TORS on 3 cases but the authors had not explained in detail how they resolved the problem of the bulky robotic arms blocking the optical sensors during navigation [8].

When adapting navigation system to TORS, several hurdles must be overcome. First, clear line of sight would be difficult to achieve with traditional robots as their arms are bulking and would easily block the line of sight. The new da Vinci SP robot may avoid this problem as the boom can rotate 360^{o} and the patient cart can be docked from both sides or from the top of the patient. Moreover, as a parallel insertion single port robot, it does not have multiple bulky robotic arms that would easily block the line of sight. Although the first author had experience operating with the da Vinci SP, he has yet to test an optical navigation system with the da Vinci SP robot and cannot definitely conclude that an optical navigation system would integrate well with this robot [9].

The ability to use IGS in robotic surgery to the skull base has distinct advantages. In open surgery, haptic feedback makes identification of bony structures, tumors and arteries easier. In robotic surgery, identification of anatomical structures now all need to rely on vision. Moreover, it would be difficulty to see beyond the surface of the structures and identify structure behind it. A navigation system can provide information for the surgeon on the location of critical structures like major arteries and nerves and also assist in ensuring completeness in resection of the lesions. The navigation system can partially compensate for the loss of haptic feedback.

Conclusion

We demonstrated our technique in integrating an electromagnetic navigation system for use in performing transoral robotic surgery in the skull base. The addition of a navigation system should improve the efficacy and safety of transoral robotic skull base operations, similar to the role in endoscopic skull base operations.

Acknowledgement

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Figure 1. The bedside surgeon applying the navigation probe to the operative field.

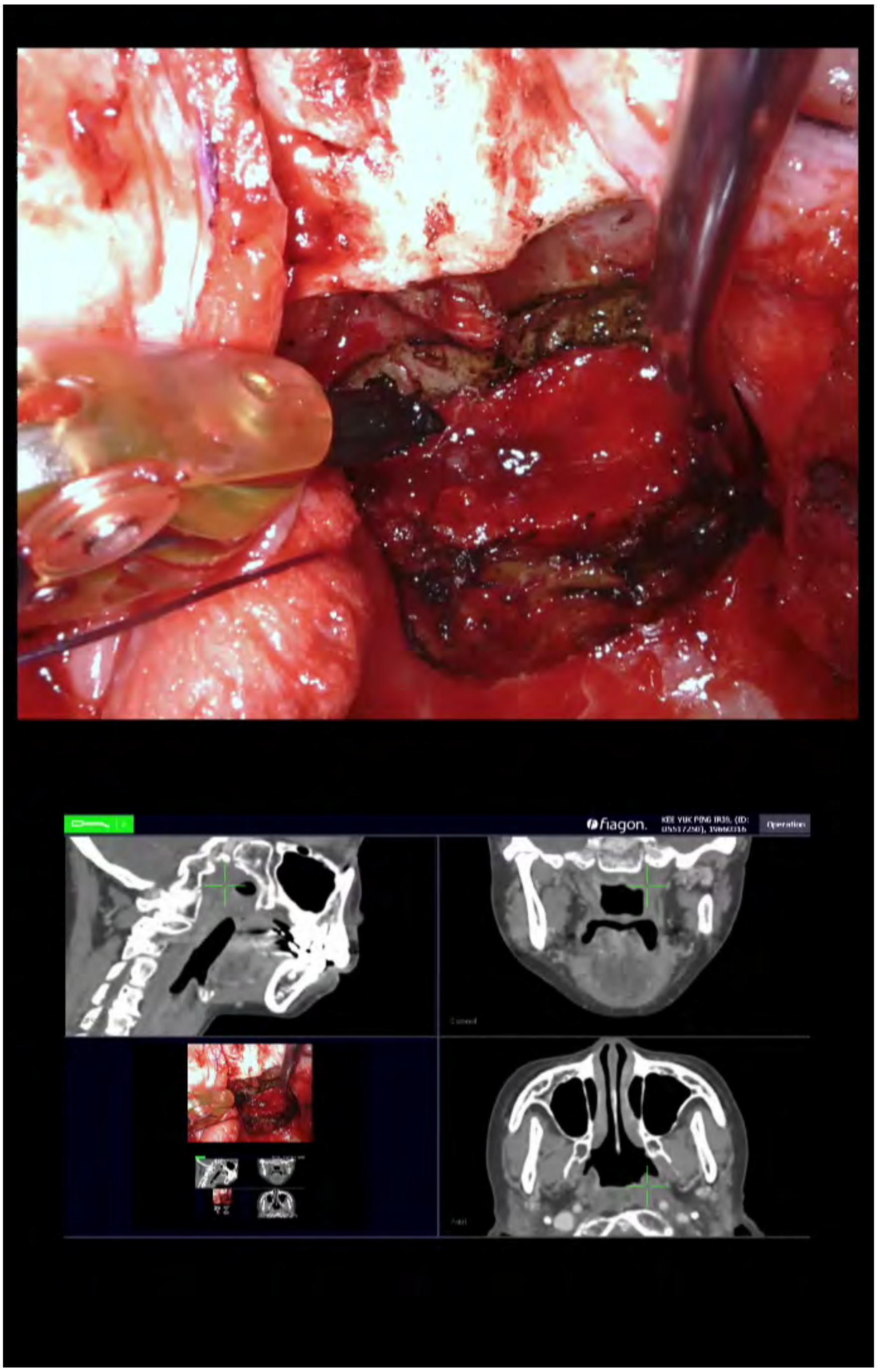

Figure 2. Locating the edge of resection from the left internal carotid artery during robotic nasopharyngectomy for recurrent nasopharyngeal carcinoma.

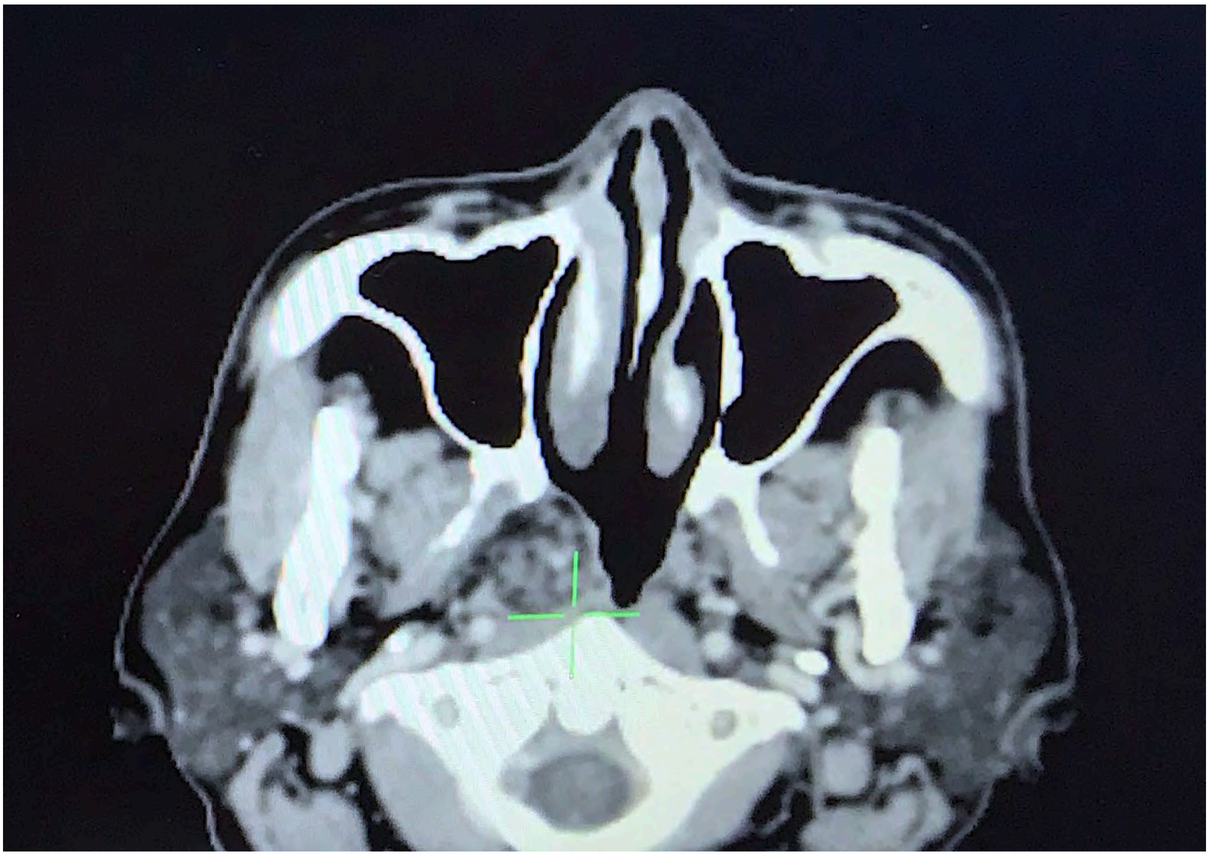

Figure 3. Axial CT scan display of the navigation system showing the pointer at the posterior edge of the tumor.

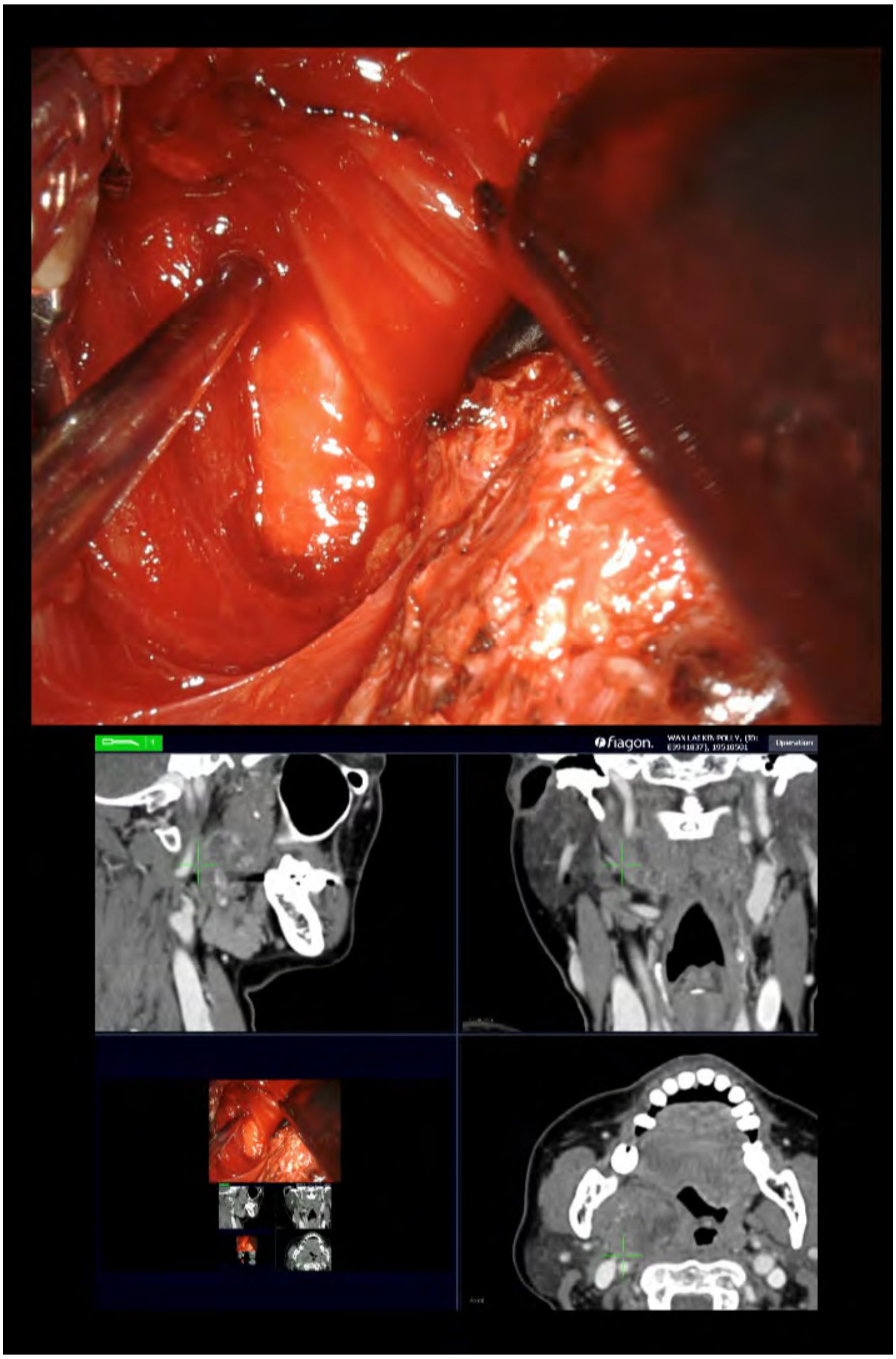

Figure 4. View of the surgeon's console of the robot with the upper part of the image showing the endoscopic view and lower part of the image showing the view of the navigation system. The pointer is pointing at the internal carotid artery, with the navigation system confirming it.

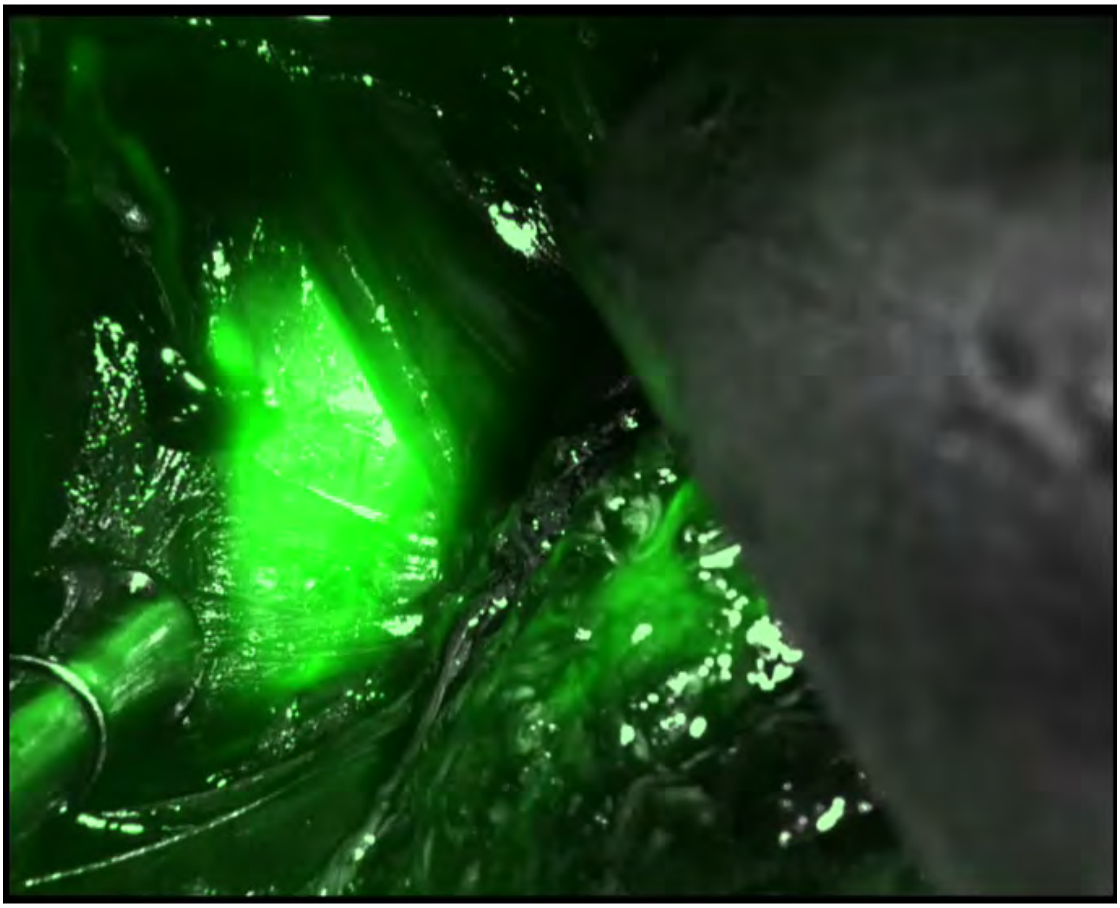

Figure 5. View of the same operating field shown in figure 4 after indocynanin green florescence, seen in the surgeon's console of the robot. The strong fluorescence immediately after injection of indocyanine green indicated the structure was an artery, the internal carotid artery.