

# The Utilization of Cranial Models Created Using Rapid Prototyping Techniques in the Development of Models for Navigation Training

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## Abstract

**Introduction** Navigation in neurosurgery has expanded rapidly; however, suitable models to train end users to use the myriad software and hardware that come with these systems are lacking. Utilizing three-dimensional (3D) industrial rapid prototyping processes, we have been able to create models using actual computed tomography (CT) data from patients with pathology and use these models to simulate a variety of commonly performed neurosurgical procedures with navigation systems.

**Aim** To assess the possibility of utilizing models created from CT scan dataset obtained from patients with cranial pathology to simulate common neurosurgical procedures using navigation systems.

**Methodology** Three patients with pathology were selected (hydrocephalus, right frontal cortical lesion, and midline clival meningioma). CT scan data following an image-guidance surgery protocol in DIACOM format and a Rapid Prototyping Machine were taken to create the necessary printed model with the corresponding pathology embedded. The ability in registration, planning, and navigation of two navigation systems using a variety of software and hardware provided by these platforms was assessed.

**Results** We were able to register all models accurately using both navigation systems and perform the necessary simulations as planned.

**Conclusion** Models with pathology utilizing 3D rapid prototyping techniques accurately reflect data of actual patients and can be used in the simulation of neurosurgical operations using navigation systems.

## Keywords

- ▶ neurosurgical navigation
- ▶ 3D rapid prototyping models
- ▶ simulation

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## Introduction

Navigation in neurosurgery has expanded rapidly in the past 10 years.<sup>1-6</sup> One might even consider this an essential tool and the ability to use it is a necessary skill in the practice of safe and modern neurosurgery.

Navigation expands in both hardware and software, but proper techniques in training remain scarce<sup>7-9</sup> Unlike microsurgery, endoscopy, and the use of high-speed drill systems, navigation presently lacks proper training programs<sup>10</sup> This might be related to the lack of suitable training models to carry out such programs<sup>9-12</sup>

The use of industrial rapid prototyping allows the creation of models that are accurate in the three-dimensional (3D) space.<sup>7-13</sup> We have developed a technique using industrial rapid prototyping processes from which accurate spatial models of the cranium, its content and pathology included, can be constructed and reproduced. Using these models, we were able to register and navigate two of the more common navigation systems (Medtronic Stealth S7 Station [Medtronic, Louisville, CO, USA] and BrainLab Kolibri [BrainLab AG, Feldkirchen, Germany]).

It is the aim of the present study to assess the possibility of utilizing models created from computed tomography (CT) scan datasets obtained from patients with cranial pathology, with the navigation systems that are currently available.

## Methodology

### Technique

Three patients with the following pathologies were selected: hydrocephalus, right frontal cortical lesion, and midline clival meningioma. The CT scan data obtained following image-guidance surgery protocol in DIACOM format of three patients as part of their surgical preparation was utilized to create a 3D model in silicon. This data was then converted into a language that could be utilized by a rapid prototyping machine to create the required printed model with the corresponding pathology embedded.

Two of the cranium models only had the skull as the outermost surface, and the last model had a skin layer created over the skull, enabling the use of conventional surface-matching techniques.

Each patient's CT data were then loaded into the respective navigation systems with the corresponding model registered in the usual manner. Both systems used in this study have registration techniques that either utilize multiple anatomical points (Medtronic: point merge; BrainLab: point registration) or a surface-matching technique (Medtronic: surface match; and BrainLab: Z touch). All models were registered using the various registration techniques provided by both manufacturers.

The model with the skin as its surface was registered directly to the systems without requiring much adjustment to the windowing of the images.

Only in the models of the skull it was required to reset the windowing within both systems to adjust the registration images of the system so as to only outline the cranium

without the overlying skin layer, to allow us to register the skull.

Following registration, a variety of conventional navigation tools and procedures conventionally used as part of neurosurgery were performed.

Data collection was performed assessing (1) the ability to register to the various registration techniques available and (2) the ability to perform the planned procedure or utilization of the planned tool.

## Results

When using Model 1 with easily identifiable skin, landmark registration was made easily in all occasions. However, in models created without the outer skin (skull only), registration using point-registration techniques was difficult (► **Table 1**). This was related to difficulties fixing specific landmarks on the software of the navigation systems once the windowing was adjusted to demonstrate the skull alone.

Surface-matching techniques, however, worked equally well irrespective of whether the models had an outer skin or not.

## Utilization of Tools

### Model 1

This model was specifically selected to allow the planning of burr holes and flaps. We were able to carry out these procedures easily utilizing the standard pointer provided by both systems (► **Video 1**).

In addition, we were also able to use the biopsy tools provided by both companies.

### Model 2

This model was selected to carry out the procedure of puncturing an enlarged ventricle.

We were able to easily puncture the ventricle using navigation techniques. In addition, we were able to also directly register an endoscope, to proceed the endoscope into the lateral ventricle and to navigate the endoscope to the region of the foramen of Monroe.

### Model 3

This model was selected as a representation of a complex skull base lesion that may be approached by cranial-based procedures, both microscopic and endoscopic.

We were able to easily use the standard probes following registration to define the lesion using both the transnasal and

### Video 1

Neuronavigation of cranial models with BrainLab and Medtronic navigation systems.

Online content including video sequences viewable at: [www.thieme-connect.com/ejournals/html/10.1055/s-0032-1330960](http://www.thieme-connect.com/ejournals/html/10.1055/s-0032-1330960)

**Table 1** Registration ability

	Medtronic		BrainLab	
	Point merge registration	Surface match	Point registration	Z-touch laser registration
Model 1: Cranium with overlying skin Pathology: Glioma adjacent to skull	Registered with good accuracy			
Model 2: Cranium only Pathology: Enlarged ventricle	Difficult registration	Registered with good accuracy	Difficult registration	Registered with good accuracy
Model 3: Cranium only Pathology: Clival tumor	Difficult registration	Registered with good accuracy	Difficult registration	Registered with good accuracy

lateral skull base routes. We were also able to use the model to navigate an endoscope to assess the possibility of a transnasal excision of the lesion.

## Discussion

With the rapid expansion of navigation procedures in the past 10 years, there is a need for systematic training of neurosurgeons using these systems. This is currently performed sporadically using basic plastic models but more often directly on actual patients during surgery.<sup>4,5,8,9</sup> The latter method is far from ideal, as there is a limit to the number of persons who can be trained at a time. Furthermore, there is often the pressure of time.

Using cadavers can be challenging. A scan of the cadaver is required, but there are regulations in most hospitals regarding sharing equipment between cadaver and patients. This would be cost prohibitive, as these navigation systems are very expensive.

Cadavers also do not have a defined pathology, thereby lacking realism when using the myriad tools and software provided for by the actual navigation systems.

Rapid prototyping techniques have been used extensively in motor and construction industries to create models.<sup>10</sup> Certain researchers have extended their use in some fields of medicine like maxillofacial surgery, orthopedic surgery, and mastoid surgery<sup>9–16</sup>

We have demonstrated that models created using this technique can be recognized by the systems as being similar to that of the corresponding patient's CT data, as we were able to accurately register them.

Following registration we were able to carry out a variety of common navigation maneuvers and carry out surgery utilizing navigation techniques.

Using rapid prototyping techniques, we believe that we can create models with pathology that is accurate in 3D space to allow navigation systems to recognize them and, as a

follow-on to this, allow them to be used as a useful tool in training surgeons to perform navigation in a more structured manner.

In addition to using these models as training tools, we also see a possibility in using these models in training surgeons in carrying out surgical procedures and planning complex cases.

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## Conflict of Interest

None

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