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The Role of DICOM in Therapy: Coping with Rise in Demand for Surgical Services

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A recent report predicted the rise in demand for surgical services to be up to 47% by 2020. Difficulties that are already apparent in the Operating Room (OR), such as the lack of seamless integration of Surgical Assist Systems (SAS) into workflow, will be amplified in the near future. There are many SAS in development or employed in the OR, though their routine use is impeded by the absence of appropriate integration technology and standards.This article explores efforts to develop strategies for improving surgical and interventional workflow assisted by surgical systems and technologies.

Appropriate integration technologies require correlative IT infrastructure as well as communication and interface standards, such as DICOM, to allow data interchange between surgical system components in the OR. Such an infrastructure system, called a "Therapy Imaging and Model Management System" (TIMMS) supports the essential functions that enable and advance images. A TIMMS provides the infrastructure necessary for surgical/interventional workflow management in the Digital Operating Room (DOR). The design of a TIMMS should be based on a suitable DICOM extension for data, image, information, model and tool communication in order to clarify the position of interfaces and relevant standards for SAS and their specific components.

Therapy Imaging and Model Management System and its Interfaces

The DICOM standard comes closest to providing the basis for the design of TIMMS interfaces. DICOM standardisation aims at providing support to fulfil design criteria derived from software engineering principles when realising ICT systems for medical activities.

Engineering of ICT systems for the assistance of surgical interventional activities implies the specification, design, implementation and testing of Computer Assisted Surgery (CAS) or IGT systems. A number of components for such systems have been developed in academic and industrial settings and are applied in various surgical disciplines. In most cases, however, they are standalone systems with specific ad hoc propriety or vendor interfaces. They can be considered as islands of IT engines and repositories with varying degrees of modularisation and interconnection.

Such a system needs to be designed to provide a highly modular structure. Modules may be defined on different granulation levels. A first list of components (e.g. high and low level modules) comprising engines and repositories of an SAS, which should be integrated by a TIMMS, is currently being compiled within the DICOM WG 24 "DICOM in Surgery".

Fig. 1 (page 32), demonstrates a high-level generic modular structure for an SAS. High-level modules are abstracted from many specific CAS/IGT systems that have been developed in recent years. In general, a combination of these can be found in most R&D and commercial SAS systems. The "Kernel for workflow, knowledge and decision management" in Fig. 1 provides the strategic intelligence for preoperative planning and intraoperative execution. Often this module or parts thereof is integrated into other engines, as required.

Steps Towards DICOM in Surgery

Medical imaging and communication standards are well defined by DICOM and are an integral part of TIMMS. Most of the Image and Presentation States (IOD), defined in DICOM, etc. are also relevant to surgery.

However, models and associated management have not been considered in DICOM intensively, except through some work done in DICOM WG 07, WG 17 and WG 22. Modelling and simulation in surgery however, are key functions for SAS pre- and intra-operatively. The interfacing of tools supporting these functions represents a new scope for DICOM.

It will be a significant extension of current DICOM efforts to complement an image-centric view with a model-centric view for developing DICOM objects and services. Some IODs that make use of the concept of a model are listed in DICOM PS 3.3 as part of annex C 8.8., "radiotherapy modules". Currently, approximately 40 modules have been specified for radiation therapy. They imply a limited spectrum of data types and data structures with different degrees of complexity, e.g. simple lists or tree structures. In the context of a TIMMS, a more comprehensive view on modelling than for example in RT, will be necessary. Not only as regards the modelling tools for generating different types of data structures, but also with respect to the modelling engine that carries out the modelling task. This engine will occupy a central position in the design of a SAS and the TIMMS infrastructure.

By default, the broader the spectrum of different types of interventional/surgical workflows that must be considered for standard interfacing support, the more effort has to be given for designing appropriate IOD modules and services. The following list contains examples of modelling tools and aspects that may have to be considered in DICOM WG 24:

• Geometric modelling incl. volume and surface representations

• Properties of cells and tissue

• Segmentation and reconstruction

• Biomechanics and damage

• Tissue growth

• Tissue shift

• Prosthesis modelling

• Fabrication model for custom prosthesis

• Properties of biomaterials

• Atlas-based anatomic modelling

• Template modelling

• FEM of medical devices and anatomic tissue

• Collision response strategies for constraint deformable objects

One of the first tasks of DICOM WG 24 "DICOM in Surgery" is to agree on a list of relevant models to be considered for DICOM IODs etc.

Following the inauguration of WG24 on June 25, 2005 during CARS 2005 in Berlin, the following roadmap has been agreed on by the members of WG24:

1. Identify and build up a user community of IGS disciplines in WG24. Initially five surgical disciplines (Neuro, ENT, cardiac, orthopaedics, thoracoabdominal and interventional radiology) have been selected. Anaesthesia is included as long as surgery is affected.

2. Encourage experts from vendor and academic institutions to join WG24. Vendors of endoscopic and microscopic devices as well as implants (templates) should be included in addition to the classic vendors of medical imaging and PACS.

3. Compile a representative set of surgical workflows (with a suitable high level of granularity and appropriate workflow modelling standards and surgical ontologies) as a work reference for the scope of WG24. Initially, three to five workflows, characteristic for each discipline, should be recorded with sufficient level of detail.

4. Derive potential DICOM services from these surgical workflows.

5. Design an information/knowledge model based on electronic medical record (EMR) related work and identify IOD extensions to DICOM.

6. Take account of the special image communication (1D - 5D) requirements for surgery and mechatronic devices.

7. Work in close cooperation with DICOM experts from radiology, cardiology, radiotherapy and related fields represented in WG1 - WG23.

8. Encourage close cooperation with working groups in international societies with an interest in this area.

9. Disseminate knowledge gained following the roadmap through workshops, conferences and special seminars.

10. Connect to integration profiles specified for surgery by IHE activities.

Conclusion

In the process of realising a standard for therapy imaging and model management in surgery, it can be expected that surgeons, interventional radiologists, hospital managers as well as buyers and vendors of OR equipment, will become aware of the new business potential made possible by a suitable DICOM standard. By using the standard, their business situation will improve not least by more streamlined workflows, but also by a safer and higher quality patient care.