Original article

The multifunctional therapy room of the future: image guidance, interdisciplinarity, integration and impact on patient pathways

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Abstract. With few exceptions the interventional rooms of the present are either imaging suites or sterile operating rooms. Their users are restricted to either percutaneous procedures or to two-staged image-guided surgery without intra-operative imaging control. Since interventional therapy of the future will be minimally invasive and since minimally invasive therapy is essentially image-guided therapy, a new physical place for these activities has to be devised: the multifunctional therapy room of the future integrates sophisticated imaging and image guidance modalities together with advanced surgical and life-support equipment in a sterile environment [1, 2, 3]. Even given a high degree of integration, this will be a complex and costly piece of medical technology. These two factors – complexity and cost – require interdisciplinary technological and medical collaboration to bring it into existence, distribute its cost and maximize usage and medical benefit. Yet another dimension of multifunctionality will be introduced and a significant impact on the care of vitally threatened patients will be exerted by using this room not only for elective image-guided therapy but also for emergent one-stop diagnosis and treatment. Motivation, technology, implementation strategies and funding of this image-guided, integrated and interdisciplinary therapy room, as well as a comprehensive approach combining emergency care and elective computer-assisted therapy (CAT), are discussed in this paper.

Key words: Minimally invasive therapy – Image-guided therapy – Technology – Operating rooms – Interdepartmental relations

Introduction

Traditionally diagnostic radiology offers imaging, images and image interpretation to its referring colleagues. Interventional radiology (IR) provides minimally invasive, image-guided methods to complement or, in some instances, replace more invasive surgical procedures. Interventional radiology, however, is limited to lesions that can either be reached and treated through a pre-existing vascular or ductal pathway or through a linear percutaneous approach. Furthermore, it is bound to the presence of efficient imaging equipment.

Surgery traditionally needs to open the body to be able to reach and act on the lesion to be treated under direct vision. The open approach accounts for a major part of the iatrogenic morbidity added to the natural course of the underlying disease. Even then the surgeon cannot normally look beyond the exposed surfaces with sophisticated imaging modalities. Surgery is bound to the presence of a sterile operating environment.

The limitation of both approaches can be overcome by an integrated concept, where modern imaging and navigation equipment is introduced into a sterile surgical environment. Integration, however, must not only comprise radiological, but also other imaging modalities (e.g., endoscopy of existing and newly created cavities) as well as surgical hardware (e.g., tools and tables), life-support equipment and others.

Shift of interventional medicine to minimally invasive methods

It appears reasonably safe to say that interventional therapy in the future will be minimally invasive therapy (MIT) whenever possible. The shift from open to closed procedures, from extensive to reduced or even percutaneous accesses is universal. It can be observed in nearly every field of medicine and in almost all organ systems [4, 5, 6, 7]. Patients specifically ask for minimally invasive methods. Interventional radiology has certainly
been one of the pioneers of MIT as has been, for example, arthroscopic and laparoscopic surgery or neurosurgical stereotaxy.

**Imaging-based diagnosis and therapy vs image guidance**

There is little doubt that image guidance plays a pivotal role in MIT. Traditionally, there has always been a kind of antagonism between diagnosis and therapy as well as between diagnosticians and therapists. This is also true for imaging-based diagnosis and therapy, which have been in use for some time, at least since the discovery of X-rays. Both activities appear as separate and unconnected medical acts. Now a third entity, namely image-guided therapy (IGT), comes into effect as the synthesis of imaging-based diagnosis and therapy. Image guidance can be defined as the direct link between imaging information and therapeutic action [8].

**Places for image-guided therapy**

*Interventional radiological suites and operating rooms of the present*

Currently there is already a whole body of knowledge about an extensive application of IGT. For example, internists are doing flexible gastrointestinal and tracheobronchial endoscopy or PTCA, surgeons are successful with neurosurgical navigation as well as laparoscopic or arthroscopic surgery, and interventional radiologists pursue vascular as well as US-, CT- and MR-guided non-vascular interventions.

Yet most of these techniques remain within the boundaries of their traditional disciplines, knowledge, technology and even physical location within the hospital:

1. Open surgery is limited by incomplete visualization that does not go beyond exposed surfaces. The localization during operations is not geometrically accurate, and the mental model not usable for targeting. Orientation is even more difficult in endoscopic keyhole surgery due to a very focused field of view. Surgery used to depend on hand–eye coordination, making exposure of the object to be treated necessary [2]. All this is true despite the existence of highly detailed map material provided by modern imaging methods. Navigation constitutes a first step to close the gap between imaging and surgical action [8]. It can be compared to a global positioning system that shows the current location in the map.

What happens if the world changes? In surgery this would be equivalent to a change in patient anatomy through, for example, resection of a parenchymal organ or reduction of a fracture. In this case obviously a new map is needed. This new map can be provided by intraoperative imaging. The kind of imaging required depends on the question to be answered: While the reduc-

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2. Interventional radiology avails itself of sophisticated imaging equipment. Still the desires of interventionists are not yet satisfied. Their next wish is the combination of several high-tech modalities such as digital subtraction angiography (DSA) with CT [12] or MR imaging [13]. The principle limit, however, of interventional suites is lack of adequate sterility for open or combined “limited-open-percutaneous” approaches and insertion of implants especially in the skeleton. Also lacking is the whole range of anesthetic equipment and the personal and technical infrastructure of a fully developed OR. Furthermore, there is no unified examination table concept even between the different imaging modalities and table constructs of, for example, CT or MR scanners which are clearly not optimized for IGT.

**Multifunctional image-guided therapy room as the physical place for IGT**

It is obvious from what is said herein that there should be synergies and possibly even a comprehensive approach. Integration of high-tech imaging equipment and an imaging-enabled OR table within a sterile environment is required. This postulation describes a physical place, the sterile image-guided therapy suite (IGTS). Surgeons might prefer to talk about an image-guided operating room (IGOR), or it may be named a multifunctional image-guided therapy room (MIGTR) of the future (OTF).

Whatever it is called, this is a complex and costly concept, not an existing product one can go out and buy presently. Its concrete implementation will vary depending on the needs of the parties involved. It will be different for a vascular center or for a trauma unit. The following and other ingredients or modules will be found in varying combinations:

1. Imaging modalities, which consist of radiological modalities (volume imaging), i.e., in terms of projective: fluoroscopy and DSA; and in terms of tomographic: MR, CT, and US
2. Optical modalities (surface imaging) with rigid or flexible endoscopes in existing cavities and in artificial cavities.
3. Guidance modalities, i.e., patient-based navigation and modality-based navigation
4. Anesthetic/surgical modalities and monitoring systems, i.e., sterile OR, life-support equipment, OR table, and surgical tools

From this list the OR table is probably the single piece of equipment that needs the most research and develop-