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Portable computed tomography performed on the intensive care unit

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Abstract *Objective:* We report on the use of portable computed tomography (CT) in an ICU setting. The additional diagnostic gain and therapeutic consequences were assessed. *Patients:* Ten ICU patients underwent 14 portable chest CT examinations. In 64% maximum intensive care was required, according to TISS28 (>40), and 42% were at a risk of mortality higher than 25% (MODS) on the day of portable CT examination. In three portable CT examinations the patients were considered not transportable and were examined directly in the patient room. All other examinations were performed in a special interventional suite directly on the ICU. *Results:* Of 14 examinations 8 (57%) resulted in a change in patient management within 48 h. All patients profited from portable CT and no hazards occurred related to CT. *Conclusions:* To perform portable CT in the interventional suite on the ICU allows imme-

diately minimally invasive therapeutic interventions and provides full ICU monitoring.

Keywords Portable computed tomography

Introduction

With advances in technology, critically ill patients increasingly require intrahospital transport for diagnostic testing. Among these tests computed tomography (CT) is one of the most frequently employed [1, 2]. Most intensivists would accept that it is better to bring a diagnostic device to a critically ill patient than vice versa. Because of the well documented hazards and expenses of transfer and its unfeasibility for some critically ill patients, the ICU or even the bedside is an appealing site

for diagnostic procedures [3, 4, 5, 6]. On our ICU we apply two different approaches with regard to the use of the portable CT scanner. One is a bedside method suitable for ICU patients who cannot be transported at all. Alternatively, there is a special interventional suite directly on the ICU where portable CT can be performed thereby offering full ICU monitoring.

Here we report our experience with portable CT which we have employed for a 1 year period in the medical and surgical ICU of our tertiary care center. The aim of this study is to introduce the portable CT technology

in ICU settings. It is presented as an addition to the other available diagnostic tools the object of which is an advanced use of diagnostic imaging (AUDI) locally on the ICU.

Material and methods

Patients

Only patients with chest CT examination were included. The CT results were compared with simultaneously performed plain chest radiographs. Ten patients underwent 14 chest CT examinations performed with portable CT in our tertiary care ICU during a 1-year period. The study included four women and six men; the average age was 56 years (range 31–82 years). For better characterization of ICU patients, they were analyzed retrospectively by scores—Acute Physiology and Chronic Health Evaluation II (APACHE II) [7], Multiple-Organ Dysfunction Score (MODS) [8], and Therapeutic Intervention Scoring System 28 (TISS 28) [9] and by the judgment by an intensivist.

Clinical environment

The interventional suite is a specially equipped 35 m² room located in the center of the ICU that can be easily reached from all patient rooms. It was designed to perform interventional and diagnostic procedures (e.g., ultrasound, fluoroscopy, and endoscopy) within the ICU (Fig. 1).

Technical equipment

The portable spiral CT scanner (Tomoscan M, Philips, Eindhoven, The Netherlands) was used. It consists of three components (gantry, CT table, and workstation) the pieces of which can be unplugged and transported separately (Fig. 2). This CT system is accumulator driven, allowing several scans in succession without recharging. The rotation time is 2 s, maximum scan area is 65 cm with a pitch of 2 (table travel of 10 mm per rotation and a slice thickness of 5 mm). The term pitch describes the ratio of table travel per rotation of the detector system inside the gantry to the slice thickness chosen. The gantry offers an independent horizontal movement of 35 cm relative to its chassis which permits the performance of head CT as a bedside method without moving the patient from bed.

Clinical evaluation

Indications for portable CT were theorized, and indication grades were ranked according to a scale ranging from 1 (essential) to 5 (not indicated):

1. Essential: CT is absolutely indicated and must be performed at once
2. Necessary: CT is important for diagnosis of disease
3. Moderate: CT could reveal some new information and could eventually be performed later
4. Not obvious: CT is elective
5. Not indicated: CT is senseless

Furthermore the diagnostic gain of CT examination was compared to portable plain chest radiographs. Additionally, for exact determination of diagnostic value of portable CT the changes in therapeutic management were noted.

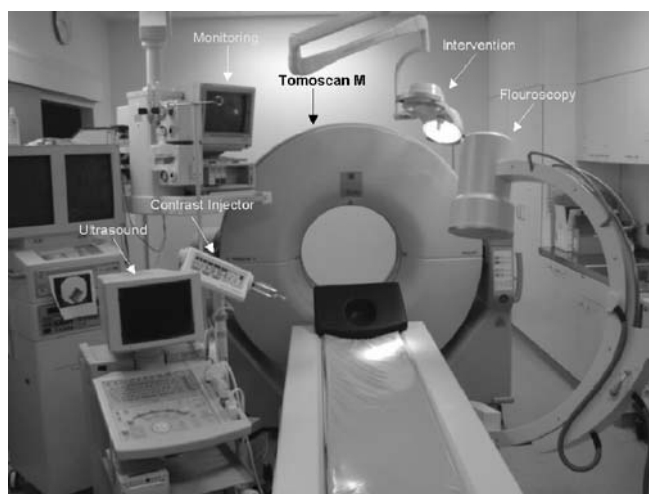


Fig. 1 Portable CT located in the interventional suite directly in on the ICU



Fig. 2 Portable CT performed directly in the patient rooms

Results

All patients had intra-arterial pressure monitoring and were connected to a portable electrocardiography monitor and pulse-oxymeter throughout the period of transport to the interventional suite and CT examination. All essential medications were continued with battery-operated perfusor pumps without interruption. For patients examined in the interventional suite the ventilation was usually maintained by means of a portable ventilator (Servo 900, Erlangen, Siemens, Germany, or Oxylog Emergency Ventilator, Dräger, Lübeck, Germany) during transport. Otherwise, advanced ventilation with high-quality devices was provided during CT examination.

Three scans were performed as bedside examinations in the patient room and 11 in the interventional suite on

Table 1 Patient characteristics, indications for CT, scores, and assessment of transportability for portable chest CT

Patient no.	Diagnosis	APACHE II	MODS	TISS 28	Indication grade	Transportability	Portable CT findings	Additional information compared to plain chest radiography findings	Change in management	Bed-side	Survival
1	ARDS due to Wegener's granulomatosis	38	18	47	2	No	Disseminated bleedings (due to vasculitis), pulmonary abscess	Yes, lung abscess	Yes, abscess drainage	Yes	No
		–	13	53	2.5	No	Hemorrhagic infarctions in chest CT	Yes	Yes, stop of therapy due to multiple hemorrhagic infarctions	No	–
2	ARDS due to varicella pneumonia	31	8	44	1	No	Pulmonary abscess	Yes	Yes, abscess drainage	Yes	No
3	Decompensated heart insufficiency	22	4	29	3	Yes	Dilated ventricles	No	No	No	No
4	Septic endocarditis with cerebral embolizations	16	8	34	2.5	Yes	No foci found	Yes	Yes, no admission for valve replacement	No	No
		–	5	32	–	Yes	–	Yes	No	No	–
5	Blunt thoracic trauma	39	13	49	1	No	I.e. lung contusion; rupture of liver, spleen and esophagus; pericardial tamponade, multiple vertebral fractures	Yes, extensive mediastinal hemorrhage	Yes, extended surgical intervention	Yes	No
6	ARDS due to Wegener's granulomatosis	17	10	47	1	Yes	Signs compatible with ARDS	No	No	No	Yes
		–	8	52	1	Yes	–	–	No	No	–
7	ARDS	–	11	45	1	Yes	Signs compatible with ARDS	Yes, extent of consolidation	No	No	Yes
8	Pneumonia, meningitis	–	6	36	2	Yes	Signs compatible with pneumonia	No	Fenestration of paranasal sinuses	No	Yes
9	SIRS, pericarditis	–	8	51	1	Yes	No infection found	Yes	No	No	Yes
		–	12	52	1	Yes	Pericardial abscess	–	Yes, surgical intervention	No	–
10	ARF	–	3	34	2	Yes	Pleural effusion	Yes	Yes, pleural drainage	No	Yes

SIRS: systemic inflammatory response syndrome

ARF: acute renal failure

ARDS: acute respiratory distress syndrome

the ICU. Patient characteristics, indications for CT, scores, assessment of transportability, and retrospective analysis of consequences are listed in Table 1. No significant hemodynamic or respiratory deterioration or any other notable mishap was observed which could have been attributed to the use of portable CT and the transfer to the interventional suite. Eight of the 14 examinations resulted in a change in patient management within 48 h. The ranges of scores for APACHE II, TISS 28, and MODS were 17–39, 29–52, and 3–18, respectively. Three patients were judged by an intensivist to be not transportable and were therefore examined in the patient room directly. Of 14 chest CT examinations five were performed on admission to the ICU in the patient room or the interventional suite.

Compared to plain chest radiographs, portable CT demonstrated a gain of additional diagnostic information in 9 of 14 cases. There were direct changes in therapy in 8 patients. In 4 patients an interventional procedure such as chest drainage was applied, and two patients were operated upon immediately after the portable CT scanning.

Discussion

The portable CT scanner can be used in a flexible manner in hospital [10, 11, 12]. In this report we describe its use for chest CT in the ICU. First, we employed the portable CT scanner in a specially designed interventional suite. On the one hand, this approach offers the advantages of full monitoring and ventilation with modern ICU ventilators using the same method as in the patient room. On the other hand, there is still the disadvantage of moving the patient to the diagnostic device instead of vice versa. Although the portability of the CT scanner used is not applied in this way, the distances and durations of transports inside the ICU are much less than those to the radiology department. Another advantage of this method is the continued availability of the intensivist on the ICU, who otherwise had to accompany the patient during transport. A possible time advantage in using the portable CT scanner in the interventional suite is limited by its technical capabilities. Both planning the examination and acquiring the data by the portable CT scanner take clearly longer than CT in the radiology department. Taking everything into account, a portable CT scanner on the ICU offers continued intensive care monitoring during examination with the equivalent overall time consumption as the CT examination in the radiology department.

Second, only if transport would be too hazardous or impossible at all a bedside CT examination was performed. This was the case in three of ten patients. This approach was rather time and effort consuming. This was not only stimulated by the method itself but also by the

underlying diagnosis of examined patients. For those patients a bedside examination was the only option for CT. Performing such a diagnostic procedure in the patient's room was expensive because of the need for many additional aides (transportation of devices, transfer of the patient from bed to CT table) and the factor of time consumption. The latter was an important consideration because the performing of CT in patients' rooms was not provided for at the time of their construction. First, there had to be an evaluation of safety according to the guidelines of German radiation protection. The indication for CT was carefully assessed following these guidelines. Other patients in such a room had to be removed, and neighboring rooms had to be shielded by portable walls made of lead.

Although these CT examinations yielded additional diagnostic information compared to conventional radiography, and although changes in therapeutic procedures were made according to these additional findings, all patients finally died at the end of their intensive care treatment. Regardless of the outcome with regard to particular patients, use of the portable CT yielded valuable, otherwise unavailable diagnostic information. Portable CT findings prompted a change in patient management in eight patients, a relatively high proportion. This figure underscores the value of images performed by portable CT. The reasonable quality of images obtained by portable CT is also reported in the literature [13, 14]. On the other hand, a specially trained radiology team is required which should be available 24 h a day, 7 days a week. The work load for the radiology department and staffing costs will increase. Hence the routine use of portable CT which serves only for very selected patients seems economically feasible only for large medical centers with a shared use of this device in the operating theater, emergency room, and ICU.

It seems that portable CT is best reserved for neurosurgical ICU patients. Gunnarsson et al. [15] report the use of the gantry only in neurosurgical ICU settings. They arranged the patients with their heads pointing to the middle of the patient rooms. This position allows easy access for the gantry able to move horizontally for rapidly performed head CT. Our study demonstrated that portable CT provides significant diagnostic gain over plain chest radiography. No hazards occurred in our patients during portable CT. Portable CT provides full ICU monitoring when performed in the interventional suite directly on the ICU.

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