Mobile Workflow in Computed Tomography of the chest

By M. Wetzl & Dr. M.S. May

This article summarizes a recently published study which evaluated a new system of controlling the operation of procedures involved in chest CT examinations using two hand-held devices, a mobile tablet device and a remote control unit. By analyzing and quantifying the workflow of the radiographers using the new hand-held mobile systems, it was found that the radiographers spent significantly more time in proximity to the patient than with conventional CT workflows.

The potential of the new tablet- and remote control- based system looks highly promising for re-assuring patients, increasing compliance, minimising re-takes and generally improving the patient experience.

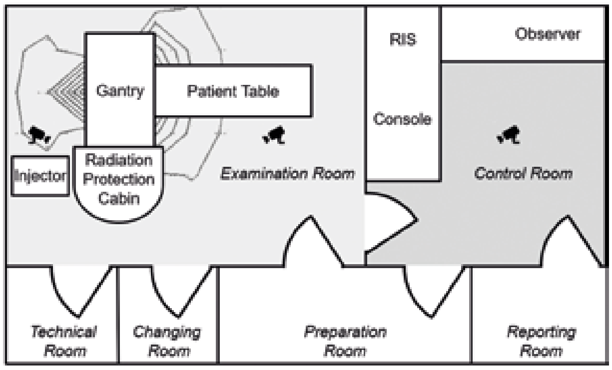

Figure 1: Schematic overview of the study setting in the examination room and in the control room (radiological information system, RIS). Isodose lines are sketched shaded black around the gantry. Positions of the ceiling mounted fisheye cameras are represented by the icons. Image reproduced from [10] ©.

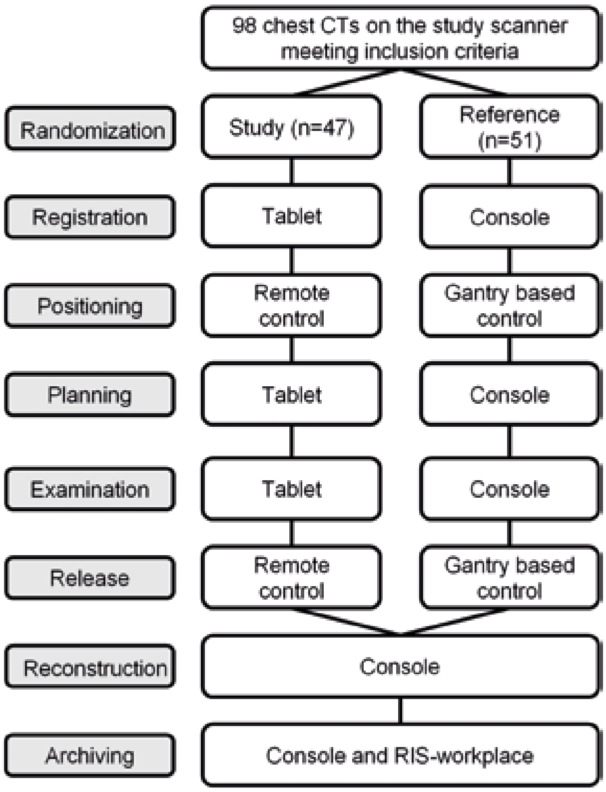

Figure 2: Flowchart of the examination workflow for the study group and the reference group. Image reproduced from [10] ©.

INTRODUCTION

Digitalization, together with the introduction of radiological information systems (RIS) and picture archiving and communication systems (PACS), is at the base of modern image interpretation and has enabled the establishment of linear workflow patterns in the carrying out of computed tomography (CT) examinations [1]. Technological advances in hardware (e.g. tube, detector, or gantry) and software components (e.g. reconstruction algorithms, dose-saving algorithms) have resulted in faster image acquisitions with higher resolution and at reduced radiation doses [2].

However, despite these developments, the actual sequence of the procedures involved in CT examinations has stayed almost the same up till now: registration of the patient in the CT machine; positioning on the patient table; planning (localizer and range definition); contrast media injection; the actual CT examination; release (of the patient from the

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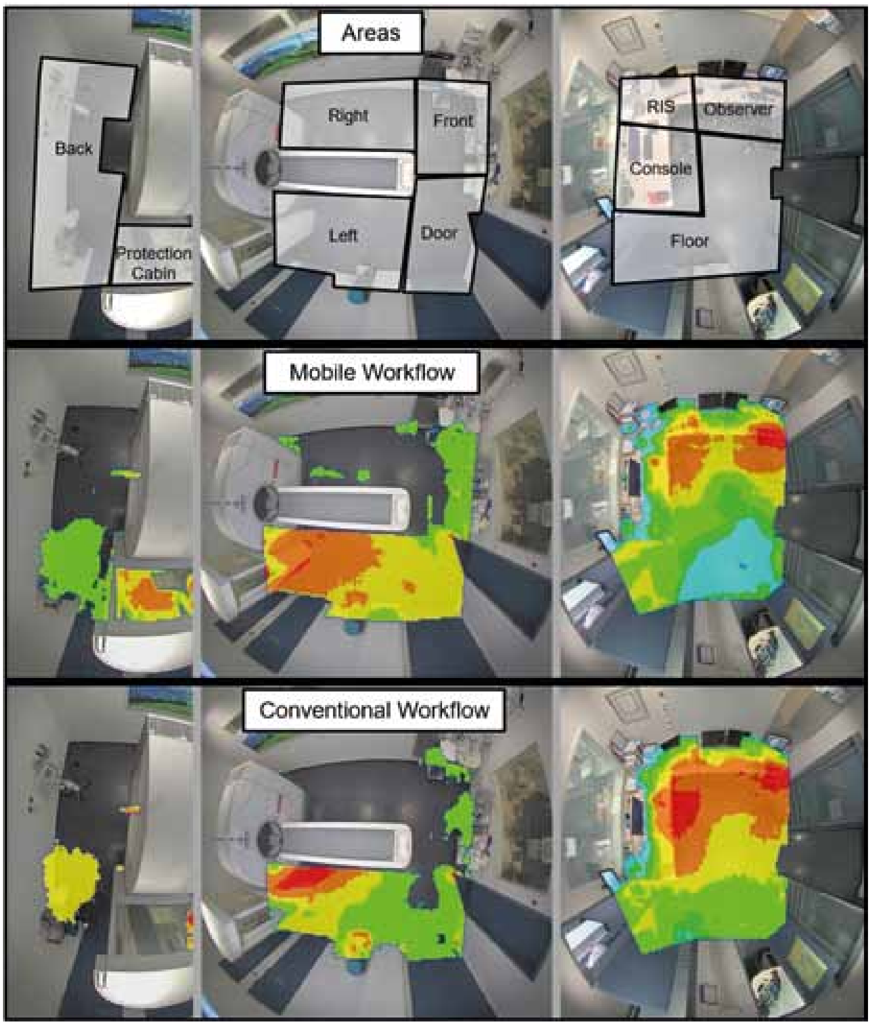

Figure 3: Perspective view of the fisheye cameras and sketched virtual areas for quantification of movement. Relative density function heat-maps (bottom rows) in false colours encoding higher (warm colours) or lower (cold colours) presence of persons in the examination room and in the control room. Image reproduced from [10] ©.

table); reconstruction of the CT dataset; archiving of the images in the PACS and documentation in the RIS. During all this, the actual contact the patient has with the medical staff is limited to the stages of initial positioning and the eventual release of the patient from the table in the examination room.

The majority of instrument settings and adjustments are controlled from a stationary operating console in a separate control room, where communication with the patient is limited to microphones and speakers. This separation between patients and medical staff severely hampers efforts to ensure patient compliance, especially in uncooperative patients. Patients who are injured, critically ill or demented, as well as pediatric cases are especially vulnerable and may require direct re-assurance, assistance and surveillance during the entire examination, even during the phase of radiation exposure [3].

MOBILE DEVICES

Mobile devices are of course already well-established in the consumer market and are also being increasingly used for home medical applications [4]. With their perfomance continuously improving in terms of computing power and battery capacity, mobile devices have recently been evaluated in various implementations in radiology departments, e.g. for patient briefing [5], diagnostic procedures [6], clinical knowledge assistance [7], case database management [8] or augmented reality in interventional procedures [9].

Recently, a new CT system (Somatom go.Up, Siemens Healthineers) incorporating a complete user interface application on a portable tablet computer has been introduced. The new system uses a wireless remote control for triggering the radiation and for patient table positioning. The mobile graphic user interface on the tablet is simple, intuitive and guides the radiographer through the whole examination in a 7-click procedure. Patient registration, planning, examination, and reconstruction can be carried out on the tablet system, while positioning and release of the patient is performed with the remote control device.

The integration of these devices into the daily clinical routine means that a redesign of the whole examination workflow now seems possible, with the aim of bringing the radiographer into closer contact with the patient.

CURRENT STUDY

In our study [10], we set out to evaluate whether the time spent by the radiographer with the patient — considered as a surrogate for patient contact and interaction — could be increased in chest CT examinations through the use of the mobile-based workflow as opposed to the conventional stationary console workflow. To facilitate the radiographers' freedom of movement in the examination room and to minimise their exposure to scattered radiation, we constructed a prototype radiation protection cabin with 3 mm lead equivalent walls in the radiation shadow beneath the gantry [Figure 1]. According to the protocol, 98 chest CTs were randomized to examination either by the mobile-based workflow in the test group (n = 47) or by conventional workflow in the reference group (n = 51). The study design is shown in Figure 2.

WORKFLOW SURVEILLANCE

The workflow was recorded by three cameras (see icons in Figure 1). Video recordings were started when the

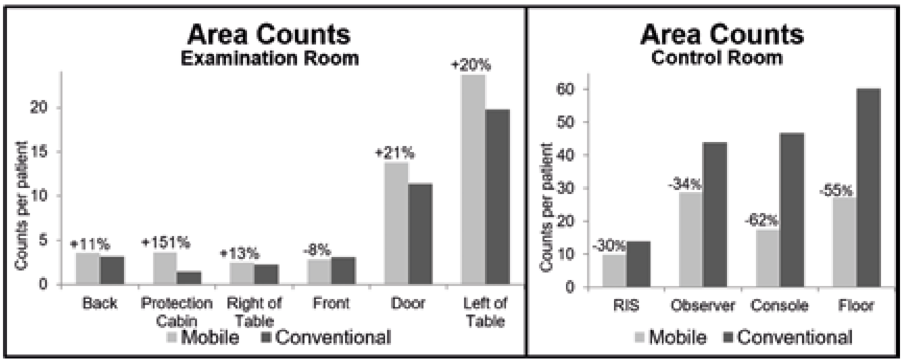

Figure 4a: Counts per patient in the predefined areas for the mobile and the conventional workflow in the examination room and in the control room. Relative changes are shown for the mobile workflow. Radiological information system (RIS). Image reproduced from [10] ©.

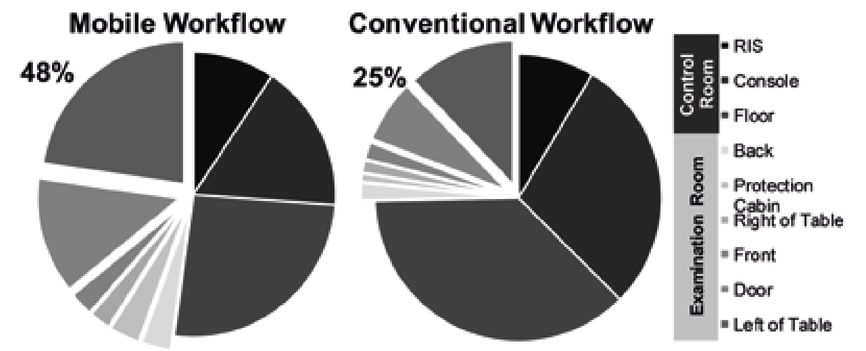

Figure 4b: Pie charts of area counts per patient of the mobile and the conventional workflow. Areas in the examination room are highlighted with an offset. The proportion of counts in the examination room relative to the entire examination is shown in numbers. Counts from the observer area were discarded in order to simulate a routine clinical setting, i.e. without an observer. Radiological information system (RIS). Image reproduced from [10] ©

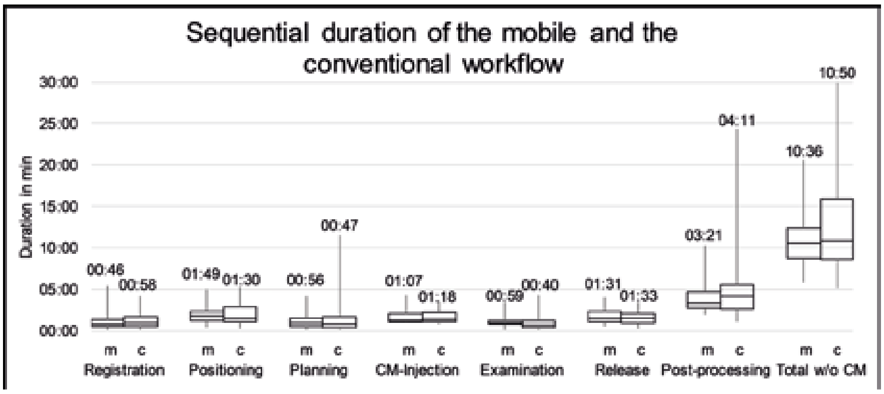

Figure 5: Boxplots of the duration of all parts of the workflow sequence for the mobile (m) and the conventional (c) workflow with the median duration per step displayed above. Contrast media (CM) injection was discarded for calculation of the total duration of the examinations. Image reproduced from [10] ©

patient was brought in from the waiting room and were stopped as soon as the archiving and documentation of the examination were finished. Dedicated software for person recognition and motion tracking was used to analyze the videos. Visualization of the movement of personnel was obtained using relative target density heat-maps, in which warm colors indicate a reactively high presence of persons in that area (hot areas, red) whereas cold colors indicate a low presence of persons (cold areas,blue) [11]. Virtual areas within the cameras' imaging areas were defined for quantitative evaluation as shown in Figure 3. Moving objects in those areas were automatically registered whenever a threshold was reached and mean counts per patient (cpp) were calculated for each area.

To support the validity of the video recordings, the duration of all workflow tasks was also simultaneously recorded manually by an observer who was located in the observer area in the control room [Figure 3].

RESULTS:

The randomisation of the patients ensured that overall the patients' characteristics were similar in both groups.

Heat-maps:

Heat-maps of the radiographers' movements provide a comprehensive overview of the radiographers' location throughout the examination sequence [Figure 3]. Hot areas decreased in the control room, especially in front of the console and across the floor area. A remaining hot area is located in front of the RIS-monitor, (integration of the RIS system with the mobile device is not yet available). The relatively constant hot area in front of the surveillance monitor in the control room can be explained by the presence of the stationary observer. In the test group it was found that in the examination room, the focal hot spot beneath the top of the patient table and the front cover of the gantry in the reference group grew to a large hot area spread out over the entire left side. Also in this group it was found that a new area of high relative target density occurred in the radiation protection cabin.

Area counts:

Area counts are a quantitaive measure of the number of times a moving person is detected in specified areas and are shown in Figure 4a. They are normalized by patient number. There was a substantial decrease of counts per patient in all areas of the control room for the mobile workflow. The highest reduction was observed in the console- (−62%) and in the floor-area (−55%). Reduction in the RIS-area was less (−30%). Overall area counts per patient were increased in the examination room, especially in the radiation protection cabin (+151%), on the left side of the patient table (+20%) and in the door-area (+21%). Figure 4b provides an overview of area counts per patient in both rooms. Counts from the observer-area were discarded in order to simulate a normal clinical routine situation, that is without observer. The area counts per patient in the examination room, (i.e. where the patient is), are almost doubled using the mobile-based workflow (48% of all cpp) compared to the conventional reference system (25%). However, in our study more than a quarter of all counts per patient (26%) are still due to an interaction with stationary systems (console 17%, RIS 9%).

Time measurements

The median duration of the exams, excluding contrast media injection, was slightly lower in the test group (10:36 min, range 05:48–20:35 min) compared to the reference group (10:50 min, range 05:03–29:57 min). This difference was not statistically significant ($p = 0.29$, Figure 5). Neither was there any statistical significance in the time spent by operators in all phases of the sequence ($0.17 \leq p \leq 0.89$). Median time spent by the radiographer in the same room as the patient increased from 3:06 min (28%) in the case of conventional routine (positioning and patient release sequences) to 6:01 min (57%) for the mobile -based system ($p < 0.05$) because the registration, planning, and examination sequences could be carried out in the examination/patient room.

DISCUSSION

Several studies have been published in which the effect on patient throughput in CT of various techniques such as intelligent scheduling or multiple radiographer workflows have been evaluated[12, 13]. However, to our knowledge, no approach has yet been presented in which the whole conventional workflow sequence has been completely re-designed. Lin *et al.* were able to show that the time physicians or medical personnel spend with patients is a determinant of patient satisfaction [14]. Although we didn't directly assess patient satisfaction, our conclusion from this study is that the increased proximity of the radiographers to the patients is beneficial for patients' compliance during the examination, especially with critical cases such as excited or confused patients. It is also well known that children's compliance often depends on their parents being in the examination room [15]. The in-room radiation protection cabin described in this study could be used for such cases and minimizes the time of separation between pediatric patient and the parent and enables voice and visual contact to be maintained without any danger of radiation exposure. The radiographers' increased freedom of movement and the in-room solution of a radiation protection area described in this study also opens up additional approaches to further improve the cost-effectiveness of CT, even if these were not yet evaluated in our study.

"... the time the radiographers spent in the same room as the patient ...was almost doubled when the examination was carried out with the help of mobile devices..."

Future software versions of the mobile application are likely to increase its functionality, so that in more developed form, mobile devices could completely replace the stationary console. If the RIS was also accessible via the mobile device, completely new design concepts of room organization would be possible. Changes in architectural lay-out could then eliminate the entire control room in favor of a radiation protection area in the examination/patient room. Other procedures that could benefit from the implementation of mobile-based control system are interventional procedures such as image guidance as described by Hirata *et al.* [16]. Indeed interventional suites in general would benefit from this approach and would require no additional equipment other than the tablet and the mobile remote control.

CONCLUSION

In our study of chest CT, the time the radiographers spent in the same room as the patient — which we consider as a surrogate for patient contact and quality in patient care — was almost doubled when the examination was carried out with the help of mobile devices. The radiographers' freedom of movement increased and their interaction with the scanner was transferred from the control room into the patient/examination room without having any effect on the total time needed for the examination.

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