Use of a 3D Camera system for precise, automatic patient positioning in CT

By Dr N Saltybaeva & Prof. H Alkadhi

Automatic tube current modulation (TCM) is an important method for the reduction of the radiation dose to which the patient is exposed in CT examinations, while still maintaining image quality. Optimal implementation of TCM relies on accurate estimates of patient size as derived from projection localizer radiographs, which however can be significantly affected by non-optimal positioning, or off-centering, of the patient.

This article summarizes the results of recent study to evaluate the effect of a novel 3D depth camera built into the CT scanner to automatically position the table for each patient.

It was found that the new system significantly reduced the extent of vertical off-centering compared to manual setting of the table height. Consequently, significant dose reductions could be obtained.

INTRODUCTION

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Ever since the introduction of computed tomography (CT) in the 1970s, the number of CT examinations has grown steadily. As a consequence, the cumulative radiation dose from medical imaging procedures to which the patient population is exposed has increased significantly [1, 2]. To address this challenge, the medical community, physicians and manufacturers of CT systems have developed and are advocating novel techniques for radiation dose optimization and reduction. Such techniques include automatic tube voltage selection, spectral shaping filtering, adaptive collimation, iterative image reconstruction and automatic tube current modulation (TCM)[3-6]. The TCM technique can be defined as a set of techniques which allow automatic adjustment of the tube current as a function of the size of the patient and the attenuation of the body part being scanned.

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This adjustment can be performed in the x-y plane (angular modulation), along the z-axis (longitudinal modulation) or as a mixture of both. Of the many other technological innovations introduced to manage CT radiation dose, TCM is generally considered to be one of the most important. Many studies have reported that the usage of TCM can result in dose reductions of up to 60%, while still maintaining image quality [7-9].

Although the practical implementation of TCM varies between vendors, tube current values are always based on estimates of patient size derived from projection localizer radiographs (LR) [10-12].

This point is extremely important, since such estimates can vary depending on the positioning of the patient in the CT gantry, resulting in different tube current values being applied by the TCM system. Inaccurate patient centering may result

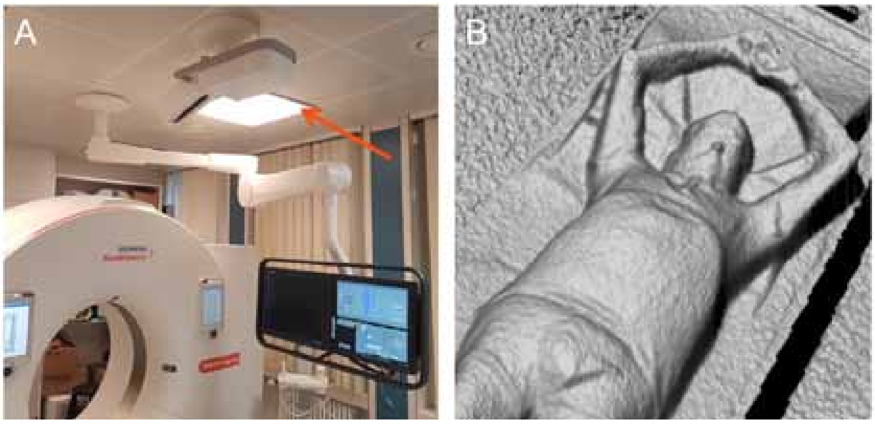

Figure 1. (A) The 3D camera (Red arrow) placed above the CT table; (B) 3D surface image of the patient obtained by the 3D depth camera.

in magnification of the acquired LR when the patient is positioned too close to the X-ray source, leading to an overestimation of the patient size. Conversely, when the patient is placed further away from the X-ray source, the LR image becomes smaller and patient size is underestimated as a result. Thus, accurate patient positioning at the gantry isocenter is crucial for evaluation of patient size and efficient usage of the TCM function. Several studies have shown that vertical patient off-centering results in undesirable consequences with regard to both radiation dose and image quality [13-17].

The most recent study of CT examinations using TCM has shown that patient off-centering of only 20 mm can cause changes in organ dose of up to 38%. Thus, the development of techniques for accurate patient positioning appear highly desirable [18].

A recently introduced CT scanner (*SOMATOM Edge Plus, Siemens Healthineers, Forchheim, Germany*) incorporates a system which enables automatic table positioning with the help of a three-dimensional depth camera. This 3D depth camera employs infrared light to measure the distance of objects from the camera, with the result that a virtual patient avatar can be created based on depth data. The geometric center of this avatar is then used for automatic table positioning.

STUDY DESIGN.

We set out to evaluate automatic patient positioning using this novel approach and to compare its performance with that of manual patient positioning as carried out routinely by our technologists. To do this we set up a study in which we analyzed image data from 120 patients who had undergone CT examinations in our radiology department between March and December 2017.

Sixty eight (68) of the patients were scanned on a third-generation 192-slice dual-source CT scanner (*SOMATOM Force, Siemens Healthineers, Forchheim, Germany*) using routine clinical abdomen (30) and chest (38) protocols. For this group of patients the table height was manually selected and set for each patient by the technologist carrying out the CT examination, with the help of the scanner`s built-in lasers Another group of 52 patients underwent abdomen (22) and chest (30) CT examinations on the novel single-source 128-slice CT scanner

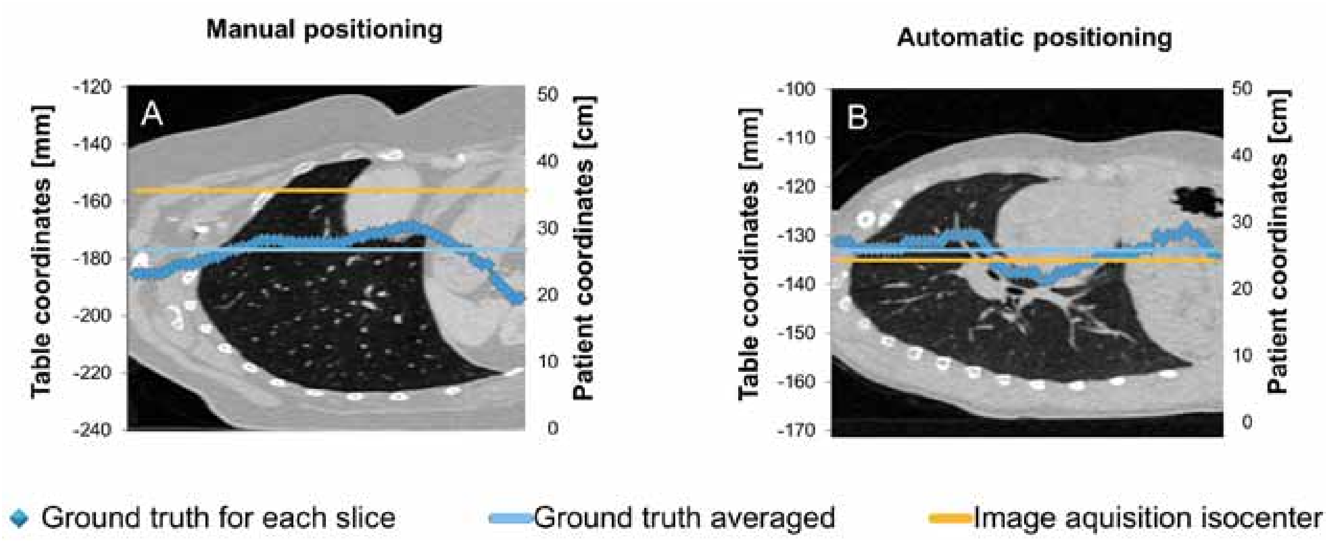

Figure 2. Representative examples of two patients who underwent chest CT examinations with manual (A) and automatic (B) patient positioning, respectively. For each imge, the ground truth table height as a function of reconstructed slice number along z-axis (dash blue), the averaged ground truth (solid blue) and the image acquisition table height (yellow) are shown.

(*SOMATOM Edge Plus, Siemens Healthineers, Forchheim, Germany*), equipped with the built-in depth camera. With this group of patients, the optimal table height was automatically determined for each patient by the CT system based on a single image from the 3D infra-red camera. The values of table height for patients positioned manually (T_{man}) and those for patients positioned automatically (T_{aut}) were then compared with the ground truth table height (TGT), which is defined as the vertical table position at which the axial center of the patient is aligned with the scanner isocenter. The axial center of the patient was defined retrospectively from the DICOM images. The vertical center for each of the reconstructed slices was calculated as the middle position between the highest and the lowest point of the extracted skin surface. Then, the central values calculated for each slice along the z-axis of the entire scanned volume were averaged in order to define the final axial center of the patient.

"…. on average, the offset in table height … could be reduced from 18 mm to 5 mm by applying the algorithm based on the patient depth image from the 3D camera …."

RESULTS

The results of our study demonstrated that automatic patient positioning significantly educes the error in patient off-centering compared to manual positioning performed by operators (p<0.005). The study showed that, on average, the offset in table height (i.e. the distance from the ideal table position to the one actually used) could be reduced from 18 mm to 5 mm by applying the algorithm which used the patient depth image from the 3D camera. For chest CTs, the average vertical off-centering was 7 ± 4 mm when using the automatic patient positioning system vs 19 ± 9 mm when the table height was set manually by technologists. For abdomen CT, the average vertical off-centering was 4 ± 2 mm and 18 ± 11 mm for automatic and manual patient positioning, respectively.

One of the most striking results of our study was that in the examinations with automatic patient positioning the offset never exceeded 15 mm, whereas in CT examinations with manual patient positioning the offset was greater than 20 mm in almost 50% of cases, with a maximal offset of 39 mm and 43 mm for chest and abdomen CT, respectively.

Interestingly, the results of our study showed that the great majority of patients (84%) undergoing chest CT examinations without automatic positioning were manually placed below the isocenter, whereas in the case of abdomen CT no particular direction of off-centering was observed.

CONCLUSION

Our study indicates that automatic individualized patient positioning using a 3D camera allows for more accurate patient centering as compared to manual positioning, resulting in improved radiation dose utilization.

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