Kellogg School of Management

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SUNIL CHOPRA AND SCOTT D. FLAMM

Body Scans and Bottlenecks:
Optimizing Hospital CT Process Flows

It was November 2005, and Dr. Steve Foster, head of radiology at a large, multispecialty hospital in the Midwestern United States, faced a challenge. His hospital had just purchased three new computed tomography (CT) scanner units and was preparing to install them. This was good news—each new scanner could provide high-resolution images in less than seven minutes, whereas the hospital's six older CT scanners required more than half an hour to scan each patient—but the new units' arrival also meant that Foster and his team had to decide how to maximize utilization of the hospital's increased scanning capacity. Foster sat down and began to review the existing process flow and plan the changes he would need to make.

Computed Tomography: The Basics

Computed tomography was a relatively new medical imaging technology. The first commercially viable CT scanner was created in 1967. It was shaped like a doughnut, and the patient was moved through the "doughnut hole" while lying down. As the patient moved, an X-ray tube rotated around the patient and acquired two-dimensional X-ray images that were reconstructed by computers as cross-sectional and three-dimensional images of anatomical organs and structures. **Exhibit 1** shows a CT scanner and a cross-sectional image of an abdomen.

Processing even the small number of images acquired by the first CT scanner took two and a half hours. Improvements in scanner technology occurred slowly until 2000, when multidetector CT scanners were developed; thereafter, the technology advanced quickly as manufacturers shifted from single-detector designs to configurations using 64 to 320 detectors, which resulted in shorter scans and better image quality. Improvements in computer processing dramatically reduced the time required to generate the reconstructed images, which numbered in the thousands. Similar to processing power in the computer industry, CT technology continued to advance in accordance with Moore's Law, representing a doubling of capability about every 18 months.[1]

Intravenously administered contrast agents were used to enhance image quality and better highlight the blood vessels in the body. CT scans were useful for diagnosis of medical diseases

[1] Moore's Law originally applied to the number of transistors that could be placed cost effectively on an integrated circuit. See Gordon E. Moore, "Cramming More Components Onto Integrated Circuits," *Electronics* 38, no. 8 (1965): 114.

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throughout the body; the high speed of the scanners enabled them to image even moving organs such as the heart.

Previous Process Flows: Single-Detector Units

Since 1998, Foster's clinic had used six single-detector CT units. In 2001 these units had been used for multiple shifts throughout the day to scan approximately 55,000 patients. Each of these scans required 32 minutes of CT scanner time. The process associated with CT scanning had been developed with this duration in mind, such that the total process time required 32 minutes (i.e., the scanner was busy either scanning or reconstructing images from the moment the patient entered the CT scan room).

The components of the process included patient preparation, the actual scan, and image reconstruction. One nurse and one CT technologist were required to carry out the tasks for each scan. The room that housed the CT scanner was a 45-second walk from the patient waiting area (**Exhibit 2**).

The steps in the scanning process were as follows:

1. The nurse first went and located the patient in the waiting area (2 minutes).
2. The nurse then moved the patient from the waiting area into the CT scanning room (2 minutes).
3. The nurse placed the IV line for contrast injection (2 minutes). At the same time, the CT technologist selected the CT scan protocol and prepared the machine (3 minutes).
4. The technologist performed the CT scan (17 minutes).
5. While the technologist was monitoring the CT image reconstruction (10 minutes), the nurse assisted the patient off the table (1 minute), returned the patient to the changing area (2 minutes), changed the linens and cleaned the CT scan room (2 minutes), refilled the contrast injector (3 minutes), and got the next patient from the waiting area (2 minutes).
6. The technologist coded and distributed the CT image (2 minutes).

From that point on, the process repeated for each new patient.

Planning for the Multidetector Units

In 2005 the hospital's management recognized the rising demand for and profitability of CT scanning and decided to add three new multidetector CT units, which were purchased for approximately $2 million each. The new scanners not only produced higher-quality images than the current units but also were about five times faster, with total scan times of 6.5 minutes per patient. Like the old scanners, they required an adjacent control room for monitoring, but they required less technologist interaction, particularly during the image reconstruction process.

As Foster and his team awaited the arrival of the new CT scanners, they realized that installing them in the same configuration as the older scanners and conducting business as usual would not maximize their value.

The new machines not only required less time for scans (2.5 minutes versus 17 minutes for the old machines), but the duration of the technologist's tasks was also reduced: selecting and preparing the CT scan protocol took 1 minute (versus 3 minutes), CT image reconstruction took 2 minutes (versus 10 minutes), and CT image coding and distribution required only 1 minute (versus 2 minutes).

Given the dramatically shortened scanning time, the CT scanner had shifted from being the bottleneck in the process to a much less time-consuming component. That meant that the team had to consider reconfiguring the scanning process to maximize utilization of the new units.

But where to start? The existing CT process—patient preparation, scanning protocol, image reconstruction, nurse and technologist tasks, and even the configuration of the scanning area—had been designed around the long scanning time of the original units. The much shorter scanning time of the new CT units meant Foster's team had to answer questions such as: Where could time be saved in non-scanning parts of the process? What changes in the physical layout would be necessary? What would be the most efficient use of the nurses and technologists? (See **Exhibit 3** for hourly personnel costs.) Would it be possible to make previously sequential tasks parallel, or to centralize certain tasks?

Foster also wondered about the implications for CT scanning for the healthcare system at large. If future technological advances continued to yield scanners with greater speed and image quality, would hospitals have more scanning capacity than needed? (See **Exhibit 4** for the growth in number of scans performed in the United States between 1998 and 2007.) What would happen when scanning capacity (or supply) eventually outstripped demand? Would it still make sense for every hospital of a certain size to have its own CT scanners?

The Challenge Ahead

The new CT scanners were a welcome addition to Foster's department, representing much shorter scanning times, higher-resolution images, and improved diagnostic capabilities. Hospital management expected him to not only use the higher throughput of the scanners to benefit the greatest number of patients, but also to maximize the return on the considerable financial investment they represented.

Foster had authorization from hospital management to make any changes he felt necessary. He knew he and his team needed to think logically and creatively in order to make the most of this opportunity.

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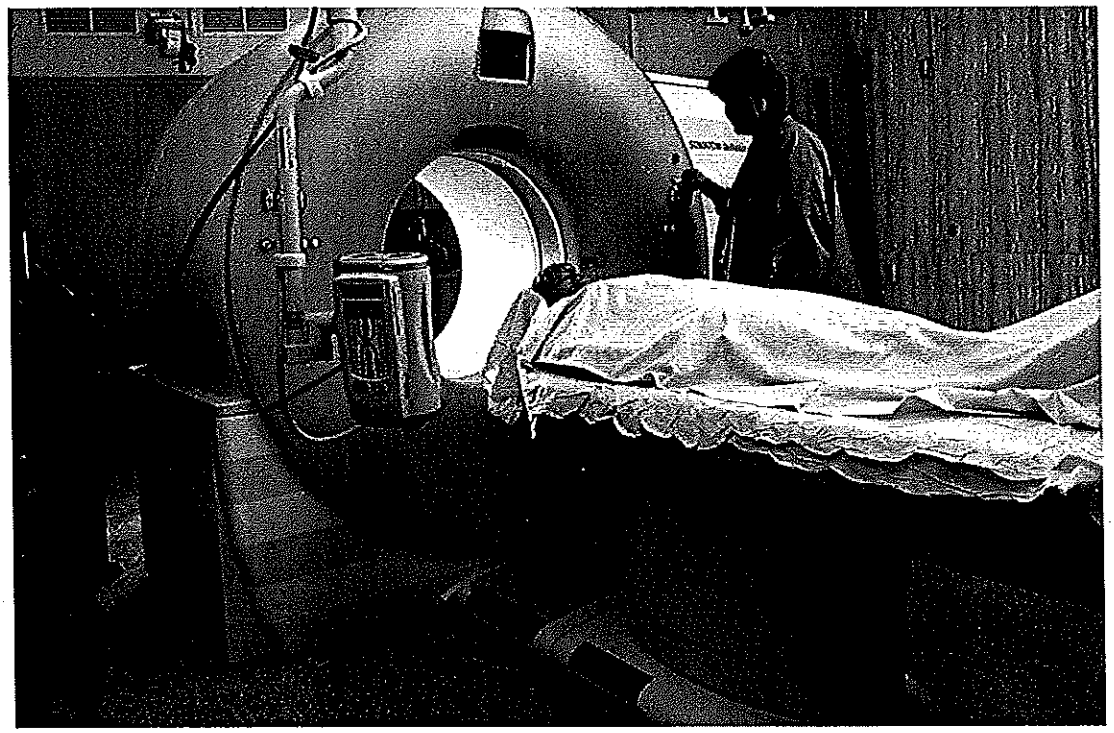
Exhibit 1: CT Scanner, 2008



CT Image, 2008

Exhibit 2: CT Scanning Area Configuration

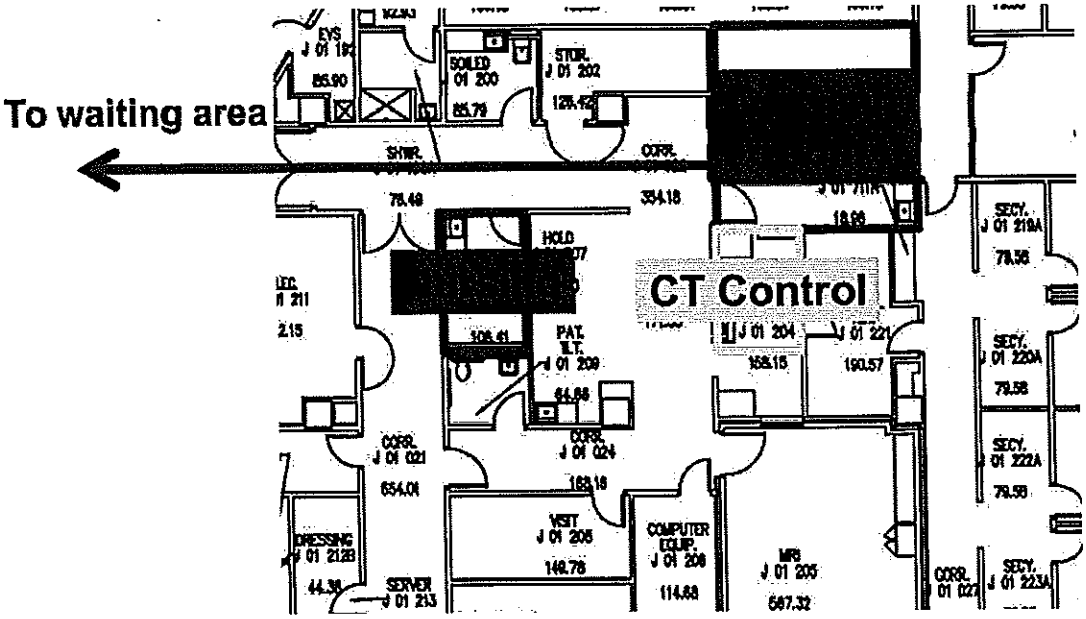


Exhibit 3: Economics of CT Scans

Revenue per CT Scan: $500

Expenses

Technologists:	$35/hour
Nurses:	$50/hour
Supplies:	$50/scan

Exhibit 4: Number of CT Scans Performed in the United States