Shifting Storage Requirements due to Modality Changes in Six Years of PACS

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A major concern with the digitalization of radiology departments is that the introduction of new imaging modalities has a large impact on the storage requirements. In this study we quantified this effect by retrospective evaluation of the data stored in our PACS over the past six years (2000-2005). This showed that the changes in imaging modalites largely effect the contribution of different modalities and the total storage required. Although the trends are clear they still seem to be unpredictable. However, looking at the past does provide an indication of the requirements in the future.

INTRODUCTION

In the past years many radiology departments have progressed into filmless operation, with some departments or hospitals being fully digitalized. However, a main concern using digital data only is determining how large the storage capacity should be and which growth should be anticipated in the coming years. To visualize this, we evaluated the data production of our Picture Archiving and Communications System (PACS) over the past six years and analyzed the influence of replacement of older imaging modalities by newer generations and the introduction of additional imaging modalities.

MATERIALS AND METHODS

The number of stored images and series per month from the PACS was recorded from January 2000 until December 2005. From these results, an estimated storage capacity per month was computed. To evaluate the cause of changes in data storage, the dates of changes in modalities were recorded.
Data were acquired from all modalities available in the PACS system, i.e.: CR (Computed Radiography); CT (Computed Tomography); MR (Magnetic Resonance); US (Ultrasound); IO (Intra-Oral radiograph); PX (Panoramic X-ray); XA (X-ray Angiography); DX (Digital Radiography); MG (Mammography); MX (Mixed); NM (Nuclear Medicine); OT (Other); RF (Radio Fluoroscopy); SC (Secundary Capture). Of these, the minor contributors were grouped into a rest group for clarity of the graphs.
All data were transferred into Microsoft Excel and graphs were computed to provide an insight into the data.

RESULTS

During the time period of this study three entirely new modalities were installed (Electron Beam Computed Tomography (EBT), CT, and MR) and nine replacements were made (table 1).
Besides the changes in the radiology department, digital equipment was also installed in other departments. From 2004 onwards, the, by now digital, dental department also stores their images in the PACS. The nuclear medicine installed their own CT system in 2005 and since then also stores the data in our PACS.

YEAR	MONTH	DEVICE	MODALITY TYPE	REPLACEMENT FOR
2001	Dec	4-MDCT	CT	spiral CT
2002	apr	16-MDCT	CT	4-slice MDCT
2004	feb	EBCT	CT	NEW DEVICE
2004	feb	New Angio room	XA	Old Angio room
2004	april	16-MDCT	CT	spiral CT
2004	aug	Digital Mammography	MG	Conventional Mammography
2004	nov	64-MDCT	CT	16-slice MDCT
2005	dec	64-MDCT	CT	NEW DEVICE
2005	dec	MR	MR	NEW DEVICE
2005	dec	3 x Digital X-ray	DR	3 x X-ray CR

Table 1. Overview of introduction of new and replacement modalities. (MDCT = Multi Detector Computed Tomography; CT = Computed Tomography; EBCT = Electron Beam Computed Tomography; XA = X-ray Angiography; MG = Mammography; MR = Magnetic Resonance; CR = Computed Radiography; DR = Digital Radiography)

CT caused major changes in the data storage. The percentage CT images of the total number of images stored increased from 16% in 2000 to 81% 2005 (Figures 1 and 2).

The percentage of the images produced per modality compared to the total production shows a decrease in all other modalities. The contribution of three other major modalities MR, CR, and US decreased from 59, 9 and 9 percent to 14, 1, and 2 percent, respectively (figures 1 and 2).

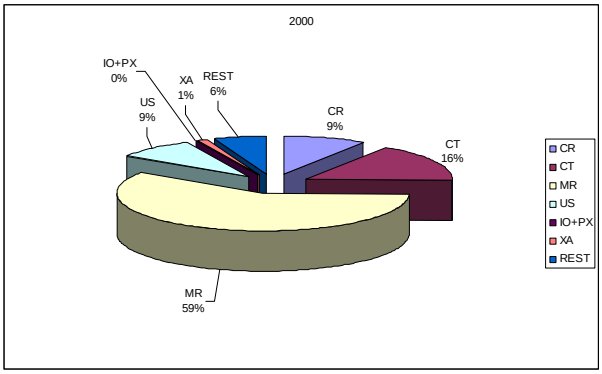

Figure 1. Pie diagram showing the percentage of the total number of images produced in 2000 for each modality. (CR = Computed Radiography; CT = Computed Tomography; MR = Magnetic Resonance; US = Ultrasound; IO = Intra-Oral radiograph; PX = Panoramic X-ray; XA = X-ray Angiography) . The REST group consisted of DX (Digital Radiography), MG (Mammography), MX (Mixed), NM (Nuclear Medicine), OT (Other), RF (RadioFluoroscopy), and SC (Secundary Capture).

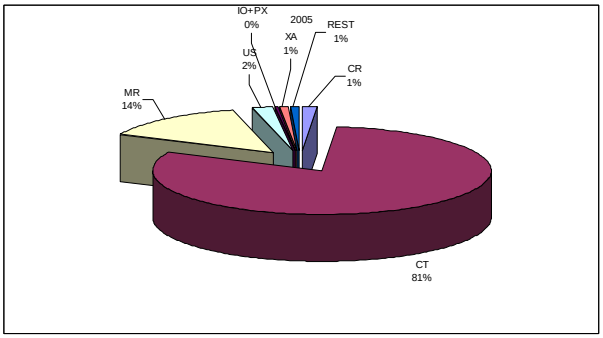

Figure 2. Pie diagram showing the percentage of the total number of images produced in 2005 for each modality. (Explanation of abbreviations see figure 1).

In figure 3 the percentage contribution per modality in images is shown for each year.

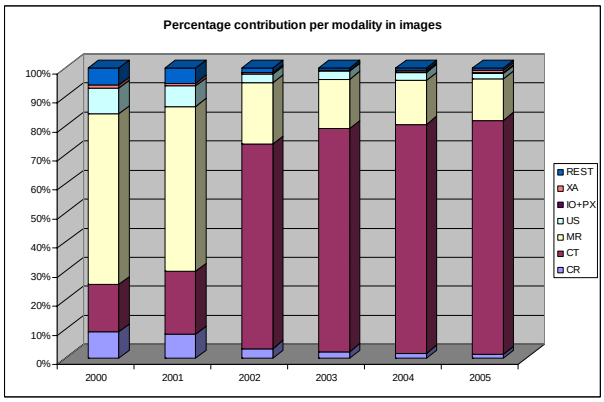

Figure 3. Percentage contribution to the total number of images produced per imaging modality type over six years. (Explanation of abbreviations see figure 1).

Similar trends are shown in the percentage of the total storage per modality (figures 4 and 5) although the influence of the image size offers different results. Again, the increase in the CT percentage is very large from 7.4 to 63.6 percent. Also, MR, CR and US decrease again but now from 21.7, 63.3 and 4.0 percent to 9.0, 17.3 and 1.6 percent, respectively. Surprisingly is the increase in IO and PX (modalities from the dental department) from 0% in 2000 to 2.9 percent in 2005.

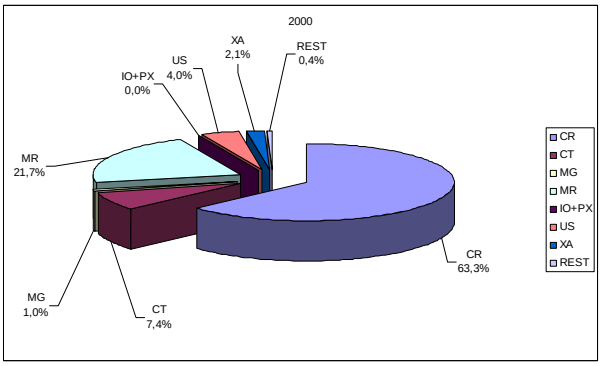

Figure 4. Pie diagram showing the percentage of the total amount of MegaBytes produced in 2000 for each modality. (CR = Computed Radiography; CT = Computed Tomography; MG = Mammography; MR = Magnetic Resonance; US = Ultrasound; IO = Intra-Oral radiograph; PX = Panoramic X-ray; XA = X-ray Angiography) . The REST group consisted of DX (Digital Radiography), MX (Mixed), NM (Nuclear Medicine), OT (Other), RF (RadioFluoroscopy), and SC (Secundary Capture).

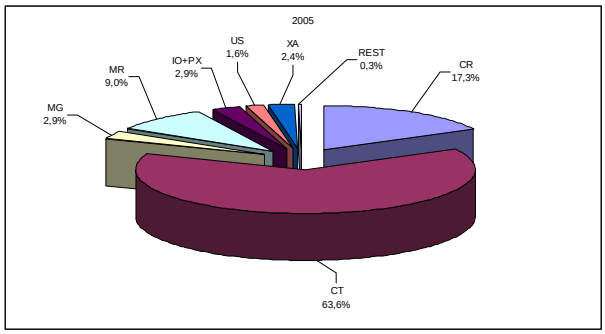

Figure 5. Pie diagram showing the percentage of the total amount of MegaBytes produced in 2005 for each modality. (Explanation of abbreviations see figure 4).

In figure 6 the percentage contribution per modality in images is shown for each year.

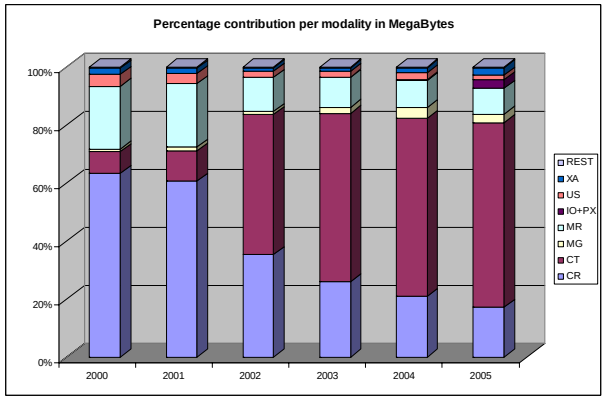

Figure 6. Percentage contribution to the total amount of MegaBytes produced per imaging modality type over six years. (Explanation of abbreviations see figure 4).

The number of images produced yearly of all modalities added together (figure 7) shows a steep increase from 1.3×10^6 per year in 2000 up to 11.2×10^6 per year in 2005. MR slightly grows in production when looking at the absolute number of images. Again, CT shows a very large growth triggered by the introduction of the first generations of MDCT in our department in December 2001 and April 2002.

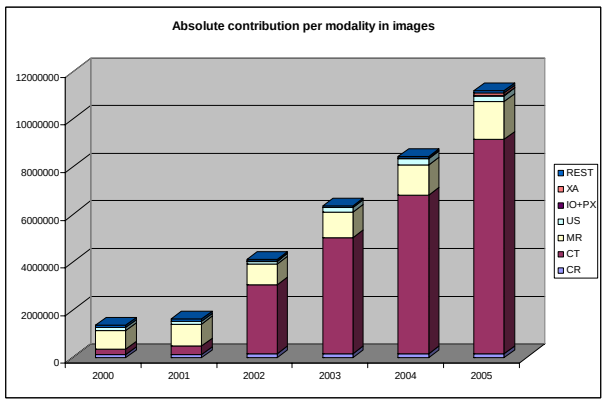

Figure 7. Number of images produced yearly in absolute numbers subdivided per imaging modality type. (Explanation of abbreviations see figure 1).

The total amount of TeraBytes (TB) produced by all modalities per year also shows a very strong increase (figure 8). Again, CT is clearly the major contributor to this increase. Moreover, in terms of MegaBytes, modalities like MG, IO+PX, US and XA also clearly show an increased production. In all cases this increase is triggered by the introduction of new, digital, modalities.

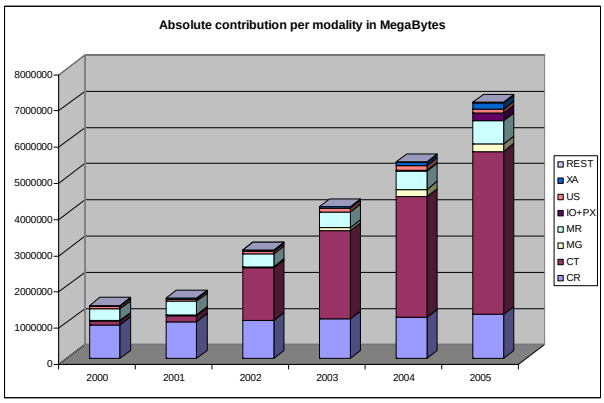

Figure 8. Amount of MegaBytes produced yearly in absolute numbers subdivided per imaging modality type. (Explanation of abbreviations see figure 4).

The total amount of computed storage in TeraBytes per year is shown in figure 9. The computed storage per year increased from 1.5 TB in 2000 to 7.1 TB in 2005. Cumulative, this adds up to a total storage of 22.8 TB in 2005.

A prediction was made in June 2005 for the storage capacity for the coming years by extrapolation of the available storage data from the previous years. An adjustment to this was made in January 2006 after the storage numbers of the year 2005 were available (figure 10). From this it was clear that the prediction of half a year earlier did not accurately estimate the storage requirements in the long run.

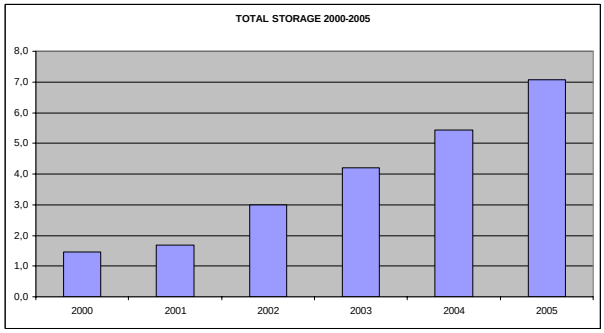

Figure 9. Yearly production in TeraBytes.

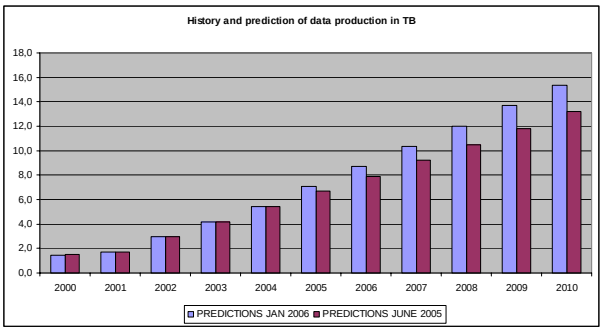

Figure 10. Yearly production in TeraBytes as given in June 2005 and January 2006. It is clear that production in 2005 exceeded the predictions made in June 2005. This forced a revision of the predictions for the years to come.

DISCUSSION

From the figures in this article it is obvious that the main reason for the increased data production is the introduction of the subsequent generations of multi-detector CT. Furthermore, digitalization of previously analogue modalities has a large impact.

Mammography data already show an increase in data production in 2003, before the introduction of the digital mammography modality. After digital mammograms became available, the old film mammographies were scanned in and stored in the PACS also upon request of the radiologist. This resulted in the storage of a large number of mammography images dated before the introduction of digital mammography. The large impact of mammography on the storage requirements in MegaBytes is caused by the per image size of on average 24 MegaBytes.

Conventional radiology (Computed Radiography) was a very stable part of the production in the past six years, both in the absolute number of images as well as in the absolute amount of storage required. However, the percentage contribution decreased significantly.

The large contribution of the IO and PX modalities of the dental department is caused by the large average size of the images of 9 and 4 MegaBytes per image respectively.

CONCLUSIONS

Introduction of new imaging systems has an enormous impact on data production and PACS storage capacity should be reconsidered prior to every change. Yearly production growth increased over 60% for the total number of images and almost 40% for the required storage capacity compared to previous years.

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