Cost-effectiveness evaluation of a Digital Radiography system

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Résumé
Évaluation médico-économique d’un système capteur-plan grand champ en radiopédiatrie
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Objectif. Évaluer une installation radiologique capteur plan grand champ (DR) dans un service d’imagerie pédiatrique dans le but d’étudier le gain en productivité d’un système numérique entièrement automatisé.

Matériels et méthodes. Étude comparative d’un système numérique capteur plan grand champ (DR) et d’une installation radiologique conventionnelle couplée à des écrans radio luminescents à mémoire (CR) réalisée dans un service d’imagerie pédiatrique sur un groupe de 193 patients. Un chronométrage des différentes phases de réalisation d’examens radiologiques simples est effectué pour moitié de la population sur le système CR et pour l’autre moitié sur l’installation DR.

Résultats. L’étude montre un gain de temps de l’ordre de 52 % en faveur du DR pour les examens d’une incidence et de 51 % pour les examens de deux incidences (p < 0.001). Une étude de flux menée sur neuf mois montre que le DR permet d’absorber 84 % de l’activité précédemment réalisée sur deux installations de radiologie conventionnelle.

Conclusion. Le capteur plan est une technologie nécessaire dans une unité de radiologie numérique sans film permettant d’augmenter sensiblement la productivité d’une salle de radiologie tout en apportant un confort ergonomique et une souplesse d’utilisation. Il est particulièrement adapté à la pratique radiopédiatrique.


Abstract
Purpose. To evaluate the impact of a completely automated digital radiography (DR) unit in a pediatric radiology department on productivity.

Materials and methods. Comparative evaluation of DR and computerized radiography (CR) units on 193 patients imaged in a pediatric radiology department. The time to complete each step of all examinations was recorded. Half of the exams were performed using CR and the other half was performed using DR.

Results. There was a 52% time gain for single projection exams using DR and a 51% time gain for dual projection exams using DR (p<0.001). A workflow study performed a 9 month period showed that DR could absorb 84% of work previously performed on two conventional radiography units.

Conclusion. DR is necessary for digital imaging departments to increase productivity, while providing added ergonomic comfort and flexibility. It is particularly well suited for pediatric imaging departments.

Key words: Digital radiography. Productivity. Ergonomics.


Setting up digital archiving systems requires imaging departments to adapt their equipment choices to this need. Two options in digital radiography are available:
• computerized radiography (CR);
• and more recently installations using digital radiography (DR), with several models available on the market today (1).

The choice of a technology should first take into account the machine’s technical capacity as well as its investment cost, which can vary as much as 100% on today’s market. The substantial changes in hospital management also require optimizing operation expenditures, often much more costly than the equipment itself. The advantages of the digital flat-panel detector units in terms of dose reduction compared to film-screen radiography or CR technology are well established (2-5); this type of system allows the radiologist to lower the parameters used (kV, mAs) without affecting the quality of the images produced (6-8).

In 2001, Sack demonstrated the efficiency of a DR unit compared to film-screen radiography in terms of the speed of image visualization and thereby a gain in examination time (9). A study conducted by Andriole in 2002 (10) compared three dedicated chest x-ray systems in terms of productivity and profitability: film-screen radiography, CR, and DR. This comparison showed a 16% increase in the number of patients imaged in favor of the DR system and a 15% time gain with DR in making the digital image available in the radiology reading room. However, to our knowledge, there have been no studies comparing DR and CR in terms of productivity in pediatric radiology.

The objectives of this study were to assess the productivity of a DR system set up in a pediatric radiology department compared to a classical CR system, then to calculate the increase in workflow handled by the DR unit during the first few months of use and the resulting changes in the department’s organization.
**Materials and methods**

**Equipment and material**

The study was conducted within a university-affiliated hospital pediatric imaging department that annually explores approximately 30,000 patients in conventional radiology per year, with 40% of its activity in emergency medicine, with a stable level of activity over the last few years. The department’s preceding situation consisted of a CR system for two conventional radiology rooms. Room 1 was equipped with a General Electric ceiling-mounted system combined with a height-adjustable floating tabletop, while Room 2 is equipped with a Siemens ceiling-mounted unit combined with a height-adjustable floating plate table. The need to replace Room 1, which was declared dilapidated because of an aging generator, prompted us to opt for an entirely automated DR system instead of a second CR system, which could overcome the deficiencies of the existing unit. The technology chosen had to be able to absorb the activity normally dedicated to the room as well as a large part of the CR activity.

The timeline to install this equipment allowed us to design a comparative study on the different stages of simple radiologic examinations on the two systems, with an assessment of the capacity of the DR system to streamline an increasing workflow. The equipment used to test the CR system was a Siemens ceiling-mounted installation with a height-adjustable floating tabletop combined with a Philips PCR AC 3000 CR system. The Aristos FX Siemens (Erlangen, Germany) DR is a Trixell flat-panel detector, with a 43x43-cm field of view and entirely automated simultaneous tube and detector displacement. The unit can be positioned vertically, horizontally, diagonally, or laterally anywhere in the room using a remote control and recognizes the examination table in its environment (fig. 1). The computer interface is a Syngo platform operating with Windows (1).

**Methods**

Three studies were conducted to meet the objectives set out. Comparative evaluations of the overall time for patient management: 193 patients from the medicine, surgery, and emergency departments of the Hôpital d’Enfants were included in the study: 111 boys and 82 girls, from 1 month to 18 years of age. The study was conducted from March to May 2004. Patients were selected only on the content of the exam request, limited in this study to simple radiographic explorations that were a very large part of the daily activity: single-projection (chest x-ray, plain abdomen, pelvis) or dual osteoarticular projection (front and lateral, for example) of the wrists, forearms, hand, elbow, knee, ankle, foot, etc. The number and age of the patients by category are listed in table I and are similar for each type of equipment assessed.

From situating the patient to verifying and archiving the image, patient management was broken down into several stages, which were then grouped into three main stages:

- **Installation stage:** installing the patient and positioning the radiographic material for both systems;
- **Incidence attainment phase,** with successively: taking the image, exposure, accessing patient data and reading for CR images; accessing patient data, taking the image, exposure, and visualization for DR images;
- **Acquisition processing phase,** including archiving, with transfer to a PACS (Agfa system) for both systems.

Each exam was carefully timed for each stage (table II) by technologists who were not part of the procedure but not in charge of taking the images (LG, TJ). The DR processing phase only comprised a simple framing of the image and was timed at 7 s for a single-projection exam and at 15 s for a dual-projection exam. In addition, for both systems, the patient undressing phase was timed, as was the time required for the image to transfer to the intranet via the PACS.

To show the results, the exams were grouped into two categories: those requiring one incidence and those requiring two incidences.

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![Fig. 1: Photo of the Aristos equipment (Siemens, Erlangen, Germany) installed in Room 1.](image)

**Table I**

Distribution of patients versus radiologic procedures carried out for each of the techniques evaluated in the study.

<table>
<thead>
<tr>
<th>No. of patients</th>
<th>Types of act</th>
<th>Mean age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper limb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower limb</td>
</tr>
<tr>
<td>Computer radiology</td>
<td>Chest/abdomin</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Pelvis</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Upper limb</td>
<td>9±4</td>
</tr>
<tr>
<td></td>
<td>Lower limb</td>
<td>6±5</td>
</tr>
<tr>
<td></td>
<td>Pelvis</td>
<td>6</td>
</tr>
<tr>
<td>Digital radiology</td>
<td>Chest/abdomin</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Pelvis</td>
<td>6</td>
</tr>
</tbody>
</table>

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The different times for each step of the procedure by anatomic segment explored were compared by means of the Student t test and the Mann-Whitney nonparametric test (SPSS software, version 11.0).

Assessment of the increase in the DR unit’s workflow during the first few months of use and changes in the department’s organization

Retrospectively, we conducted a workflow analysis over 1 year beginning in June 2004, starting 1 month before the DR was installed. From the listing of radiological procedures identical to those mentioned above, the activity curves of the two units in operation in the department were established: Room 1 equipped with the DR and Room 2 equipped with a ceiling-mounted system combined with a CR unit, so that the results could be compared over time to determine the workflow over the long term.

The changes in organization and distribution of work tasks between technologists when the DR unit was installed were also studied.

User satisfaction survey

A satisfaction survey was conducted among the pediatric radiology department’s 14 technologists. We used the same criteria as Andriole (10) in his 2002 study to determine the users’ opinions on ease of use, execution speed, image quality, and the user-friendliness of each of the two systems:

- +2 for DR much better than CR;
- +1 for DR better than CR;
- 0 the same level of satisfaction for the two systems;
- −1 for CR better than DR;
- −2 for CR much better than DR.

Results

Comparative assessment of the overall patient management time

The results for time are presented in Table II by anatomic region and by radiographic system.

The main result was a significant gain in the mean time needed to carry out the exam with DR compared to CR, with a 48%-59% reduction depending on the anatomic region (p < 0.001). The reduction was a mean 55% for the exams with one incidence and 51% for the exams with two incidences. This gain was mainly observed not for the installation phase but rather for the incidence attainment phase and particularly for the image-processing phase, with time gain values reaching 42% and 83%, respectively. It should be noted that technologists spent a mean 15 s covering approximately 15 m separating radiodiagnosis Room 2 and the CR reading system, with sometimes a waiting time if the other room was occupied.

The undressing phase was timed at a mean of 40 s, and the transfer to the intranet via the PACS phase was timed at 95 s for both systems, for a total of a mean 135 s for patient management beyond the actual radiographic exam.

Consequently, the analysis of the complete patient management time, from the waiting room to putting the image on the intranet, shows that the technologist was busy for a mean 403 s for the CR and 266 s for the DR.

Assessment of the increased workflow of the DR unit during the first months of use

The number of procedures carried out on the two installations during the workflow analysis period was 1,005 for the lowest of the 2 months and 1,384 acts for the highest month. The monthly CR activity dropped from 1,382 to 124 acts, whereas over the same period the DR activity progressed from 2 to 1,223 procedures (fig. 2).

Before acquiring the DR, half of the radiographic procedures were performed on each of the existing installations, in the GE and Siemens rooms, with a preference for the GE room. The increased DR workflow quickly stabilized at approximately 84% of the overall activity of the department because it was largely preferred by the technologists, whether they were part of a team during scheduled work or alone in emergency situations. The CR machine remains in use mainly for column stand or limb images and for certain incidences done on patients in bed or on a stretcher; it sometimes serves as a second room at times of overflow.

The department’s organization has also been modified: one rotation cycle with two technologists allows x-raying three patients on the DR installation versus two for the same time unit with the CR system, a consequence of the time gain in visualization and image processing provided by the DR system (fig. 3). These changes were easily accepted and managed by the technologists.

User satisfaction survey

Overall, the 14 professionals reported greater satisfaction with the DR unit than with the CR system, with a mean +0.92 for the system’s user-friendliness, +1.14 for ease of use, +1.5 for image quality, and +1.85 execution speed. Three individuals, however, found the two systems to be equivalent, one for ease of use, one for user-friendliness, and the other for image quality.

![Table II](https://example.com/table-i.png)

<table>
<thead>
<tr>
<th></th>
<th>(s)</th>
<th></th>
<th>(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>Equipment installation</td>
<td><strong>Installation</strong></td>
<td>Equipment installation</td>
</tr>
<tr>
<td>Patient installation</td>
<td></td>
<td>Patient installation</td>
<td></td>
</tr>
<tr>
<td><strong>Incidence</strong></td>
<td>Incidence attainment</td>
<td><strong>Incidence</strong></td>
<td>Accessing patient data</td>
</tr>
<tr>
<td>Exposure</td>
<td></td>
<td>Incidence attainment</td>
<td>Exposure</td>
</tr>
<tr>
<td>Accessing patient data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CR reading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td>Treatment access</td>
<td><strong>Treatment</strong></td>
<td>Treatment and archiving</td>
</tr>
<tr>
<td>Treatment and archiving</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tableau III
Result of timed procedures, expressed by anatomic region studied for each unit, time gain generated by DR in percentage compared to CR. The results of the comparisons of the means are shown in the last column, except for pelvic images for which the patient numbers were too low (*).

<table>
<thead>
<tr>
<th>Exams</th>
<th>No.</th>
<th>Phase</th>
<th>Mean time (s)</th>
<th>Total</th>
<th>Nb</th>
<th>Phase</th>
<th>Mean time (s)</th>
<th>Total</th>
<th>Gain</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper limb</td>
<td>42</td>
<td>Installation</td>
<td>19±24</td>
<td>230±87</td>
<td>29</td>
<td>Installation</td>
<td>9±06</td>
<td>53%</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incidence</td>
<td>143±39</td>
<td></td>
<td></td>
<td>Incidence</td>
<td>102±32</td>
<td>126±33</td>
<td>27%</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>68±59</td>
<td></td>
<td></td>
<td>Treatment</td>
<td>15</td>
<td>88%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation</td>
<td>28±11</td>
<td></td>
<td></td>
<td>Installation</td>
<td>7±07</td>
<td>75%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower limb</td>
<td>21</td>
<td>Incidence</td>
<td>183±63</td>
<td>267±101</td>
<td>18</td>
<td>Incidence</td>
<td>96±22</td>
<td>118±22</td>
<td>48%</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>56±37</td>
<td></td>
<td></td>
<td>Treatment</td>
<td>15</td>
<td>73%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest/abdomen</td>
<td>26</td>
<td>Incidence</td>
<td>156±49</td>
<td>230±69</td>
<td>46</td>
<td>Incidence</td>
<td>100±38</td>
<td>119±37</td>
<td>36%</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>51±29</td>
<td></td>
<td></td>
<td>Treatment</td>
<td>7</td>
<td>86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation</td>
<td>18±02</td>
<td></td>
<td></td>
<td>Installation</td>
<td>7±07</td>
<td>61%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>5</td>
<td>Incidence</td>
<td>252±56</td>
<td>347±59</td>
<td>6</td>
<td>Incidence</td>
<td>129±36</td>
<td>143±33</td>
<td>49%</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>77±13</td>
<td></td>
<td></td>
<td>Treatment</td>
<td>7</td>
<td>91%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion
The values found for timing are unequivocal. DR technology is significantly faster in the three exam phases. These results have substantiated the choice made for DR in a pediatric radiology department with a high level of scheduled and emergency activity and also reassured the institution that the investment was worthwhile.

In the installation phase, the automated displacements of the DR system provide a considerable gain in time in setting up the equipment. In the incidence attainment phase, the DR image can be visualized 6 s after exposure, whereas 35-55 s are required for CR depending on the size of the screen. Presetting of the aperture as well as automatic marking considerably reduce the image-processing phase time. The all-in-one DR system provides a substantial time savings in the movements of personnel, contrary to the CR system, which requires coming and going between the diagnostic x-ray room and the plate reader.

The workflow analysis over 1 year, from June 2004 to June 2005, shows an increase in the DR system’s workflow, by 69.2% in October — when the installation began full operation — and 89.2% in December. These numbers can be explained by the personnel’s attraction for this revolutionary technology. The speed with which a high-quality image could be visualized and its ergonomics make it a pleasant tool.
to use. The personnel in pediatric radiology were able to give the patient, the child’s parents, as well as the hospital’s clinical personnel the advantages of this technology, reducing waiting time for all involved.

The gain in productivity obtained by the installation freed up technologist time and required another patient management philosophy. It allowed the personnel to spend more time with the patient, on hygiene, and on archiving and distributing images to clinicians. On the other hand, this requires a minimum of two if not three technologists to ensure the machine’s continuous use when the department is busy.

However, in its current configuration, the DR cannot always absorb all the work done on two radiological installations. Several situations require use of CR (beyond the x-rays taken outside the department for emergencies, sterility requirements, etc.): • the size of the detector precludes any use on patient beds or stretchers. • as for any motorized system, manual use of the ceiling-mounted x-ray tube is extremely difficult, requiring substantial physical effort on the part of the personnel. Setting up a bed in the radiology room is cumbersome because of the examination table set-up. These disadvantages substantially increase patient management time in these situations, surpassing the time required for the same image attainment on a conventional installation, thus canceling out any time gain, which is why this activity is kept in the second radiography room. • the exploration zones above 43 cm (legs and femurs of adolescents, teleradiographies of the spine and the lower limbs) can soon be explored using multiple exposures and image-fusion software.

Flat-panel detector radiology is a new technology that provides a considerable gain in time in producing standard x-ray exams. The upcoming arrival of teleradiography software could allow us to expand its sector of investigation. The investment cost of this type of equipment can be amortized by the installation’s increase in productivity. Its ergonomics and user-friendly imaging system make it a simple and pleasant tool to use, confirmed by the technologist personnel’s enthusiasm.

Conclusion

Flat-panel detector radiology is a new technology that provides a considerable gain in time in producing standard x-ray exams. The upcoming arrival of teleradiography software could allow us to expand its sector of investigation. The investment cost of this type of equipment can be amortized by the installation’s increase in productivity. Its ergonomics and user-friendly imaging system make it a simple and pleasant tool to use, confirmed by the technologist personnel’s enthusiasm.

References