Handheld computers offer many features that can improve workflow for healthcare providers. Wireless networking capabilities of current state-of-the-art handheld computers provide a platform for real-time patient management. For example, the wireless-enabled personal digital assistant (PDA) allows medical and nursing staff to access electronic patient records. The tablet PC is a newly developed handheld computer that has larger display than a PDA. This may be useful in radiological image review.

A test of this concept involved the observer performance in the interpretation of the abdominal plain radiograph for patients with suspicious urolithiasis. Detection of urolithiasis on a tablet PC was compared to soft-copy reading at a PACS (Picture Archiving and Communication System) workstation.

No statistically significant difference could be detected between the two observational modalities.

The current small-scale study supports the use of the tablet PC in the review of high resolution computed radiographs in some clinical applications without compromise of the diagnostic accuracy.

Key words: Microcomputers, Radiology information systems; Picture archiving and communication system (PACS)

MATERIALS AND METHODS

Image Selection and Display

Eighty patients (46 men and 34 women) who were referred to our department for intravenous urography (IVU) examinations with clinically suspected urolithiasis between November 2001 and December 2002 were enrolled into the study. CR images were collected prior to the injection of contrast agent in each IVU examination. The CR images were obtained on a Picker 12800-000i digital radiography system with a high resolution detector (Picker, Cleveland, OH) using an incremental technique with 120 KVp and 200 mA. The images were stored on a PACS system (Carestream Health, Rochester, NY) for further analysis.

The CR images were analyzed on a tablet PC (Surface Pro 3, Microsoft, Redmond, WA). The tablet PC was connected to the PACS system via a wireless connection. The CR images were displayed on the tablet PC using the PACS software. The diagnostic performance of urolithiasis detection on the tablet PC was compared to the detection sensitivity using traditional soft-copy reading at a picture archiving and communication system (PACS) workstation.

Results

No statistically significant difference could be detected between the two observational modalities. The current small-scale study supports the use of tablet PCs as a mobile PACS.

Key words: Microcomputers, Radiology information systems; Picture archiving and communication system (PACS)
Two CR readers were used; the Agfa ADC solo (Agfa-Gevaert AG., Germany) and the Fuji FCR XG1 (Fuji Photo Film, Japan). Image resolution was 2048 × 2496 pixels for the Agfa CR and 1760 × 2140 pixels for the Fuji CR.

A total of eighty CRs obtained from the 80 patients (46 men and 34 women) were evaluated. The mean age was 49.7 years (males 57.5 years, females 42.5 years) and the age range was 19-83 years. The results of the IVU study and clinical records were used as the gold standard to determine the presence of renal or ureteral stones.

Two general radiologists who were blinded to the clinical information and results of IVU reviewed each image independently on a tablet PC (TC1000, Hewlett-Packard, USA) and a diagnostic PACS workstation (IMACS, Rattan, Taiwan). The interval between reading sessions was 7 days. The tablet PC was equipped with a 10.4 inch color monitor having a resolution of 1024 × 768 pixels. The PACS workstation was equipped with high quality grayscale CRT monitor (MGD 521, Barco, Belgium) with a resolution of 2048 × 2560 pixels. The same PACS viewing software (IMACS, Rattan, Taiwan) was used for each machine and image processing functions such as window/level, zoom and pan were allowed during image interpretation. Calibration for PACS monitor was performed according to DICOM (Digital Image Communication in Medicine) GSDF (Gray Scale Display Function) specification. No calibration was performed for the color LCD (liquid crystal display) of the tablet PC because there is no commercial available

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**Figure 1.**

1a. ROC curves for renal stone detection (observer 1).  
1b. ROC curves for renal stone detection (observer 2).  
1c. ROC curves for ureteral stone detection (observer 1).  
1d. ROC curves for ureteral stone detection (observer 2).
DICOM calibration tool for the color LCD. Only minimal statement have been mentioned at DICOM part 14 and supplement 100 for color LCD calibration; and color display systems may be calibrated to the GSDF for the purpose of displaying gray-scale images.

**Observer Performance**

Each radiologist scored the presence of urolithiasis on a five-point confidence scale. The presence of renal or ureteral calculi was evaluated using the following scoring system: 1, definitely negative; 2, probably negative; 3, indeterminate; 4, probably positive; and 5, definitely positive. We divided urolithiasis into two groups: renal stones and ureteral stones. With IVU and clinical follow-up as the reference standards, receiver operating characteristic (ROC) analysis was performed[8]. The ROC curves for each radiologist were obtained and the area under the ROC curve (Az) indicative of the detection accuracy was computed by use of statistical software (SPSS for Windows Version 11.0, SPSS, USA). Statistical significance of the results was reported as the 95% confidence intervals for the mean difference of Az values.

**RESULTS**

There were 28 kidneys with renal stones in the 160 kidneys and 24 ureteral stones in the 160 ureters. The sizes of renal stones and ureteral stones were between 4mm and 3cm. The ROC curves for both observers and of the renal and ureteral stones were plotted separately for each modality and there were no significant differences between the two modalities (Fig. 1). The averaged Az rated 0.924 and 0.927 for the detection of renal stones using the tablet PC and CRT monitor, respectively (Table 1). The averaged Az for detecting ureteral stones was 0.828 and 0.783 for the tablet PC and CRT monitor, respectively (Table 1). Averaged observer performance for the detection of renal stones exceeded detection of ureteral stones using both tablet PC and diagnostic PACS workstation. At P <= 0.05, the difference between these two observational modalities on the detection of urolithiasis was not statistically significant.

**DISCUSSION**

Many studies have supported the use of handheld computers as a teleradiology terminal for busy radiologists [1-7]. The next phase of this digital revolution in medicine is taking place, through the dissemination of powerful handheld computers.

Handheld computers present many features of clinical relevance including improved personal information management, decision support via access to educational materials, and remote access to radiology-related information systems [1-3]. Furthermore, the use of low resolution notebook computers or personal digital assistants (PDAs) to display emergent head CT images for bedside interpretation has been reported in the literature[4-6].

The present study is the first to evaluate the observer’s performance in the interpretation of high resolution radiology images by using a tablet PC for the presentation. The results revealed no significant reduction in the accuracy on the tablet PC, as compared to the PACS workstation. A recent report showed that for detecting urinary calculi, the diagnostic performance with soft-copy images viewed on an LCD monitor was comparable to that of soft-copy images viewed on a high-resolution video monitor [9]. These encouraging results provide evidence supporting the utility of commercially available tablet PCs as a PACS terminal for clinical review.

Our study should not be interpreted as a blanket endorsement of the tablet PC for image-based diagnosis. Only urolithiasis in abdominal plain film was evaluated in this study. Furthermore, the small patient number may have obscured the differences in interpretation that will only be apparent with a larger study population and/or different clinical maladies. More comprehensive studies are necessary before the routine use of a mobile PACS system can be confidently undertaken. In our experience, the tablet PC is not suitable for primary radiologic diagnosis. It is more time-consuming using the tablet PC than a PACS

<table>
<thead>
<tr>
<th>Observer</th>
<th>Az (SD) for renal calculi</th>
<th>Az (SD) for ureteral calculi</th>
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<tbody>
<tr>
<td></td>
<td>Tablet PC</td>
<td>CRT monitor</td>
</tr>
<tr>
<td>1</td>
<td>0.917 (0.04)</td>
<td>0.910 (0.04)</td>
</tr>
<tr>
<td>2</td>
<td>0.930 (0.04)</td>
<td>0.943 (0.03)</td>
</tr>
<tr>
<td>Average</td>
<td>0.924</td>
<td>0.927</td>
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workstation, because the image transfer time is longer with wireless LAN, and because the subsequent image manipulation is slower using the less computationally robust tablet system. The monitor of tablet PC is small, which may hamper group interpretation and obscure fine details. Moreover, the special coating on the monitor that allows for free-form use of a pen can further degrade image quality. Eye strain may occur when reviewing large amount of images (although this is also a problem with a PACS system). For long-time usage, the short battery life and the large amount of heat generated by tablet PC should also be taken into consideration. Possible security problems from wireless medical images transfer may represent a potential for concern. The transfer speed using standard wireless LAN protocol (IEEE 802.11b) is 11Mbits/sec, which is slow for delivering large medical images. For example, it typically took over 30 seconds to transfer a single CR image in our system. This may not be acceptable for a busy physician. Using more advanced wireless LAN protocol (IEEE 802.11g) with 54Mbits/sec transfer rate may shorten the network transfer time. However it is still slower than wired LAN.

Despite these limitations, the tablet PC presents a potentially useful means of obtaining and evaluating images in a highly portable way. Clinicians can literally evaluate the imaging findings on the bedside. This may ultimately speed clinical image review.

CONCLUSIONS

The present small-scale study supports the use of the tablet PC in the review of high resolution computed radiographs in some clinical applications without compromise of the diagnostic accuracy.

ACKNOWLEDGMENTS

This study was supported by grant 92-S091 from the National Taiwan University Hospital, Taipei, Taiwan.

REFERENCES:

Tablet PC as a PACS workstation

使用平板電腦作為影像儲存與傳輸系統之工作站：接收者操作特徵曲線（ROC曲線）分析

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手提電腦的便利性改善了我們醫療從業人員的工作流程，無線網路的發達更為手提電腦的使用者提供了一個可以即時處理病患問題的平台。舉例來說，配備無線網路的掌上型電腦（PDA）能讓醫師與護理人員立即查詢病患的檢驗資料。而新近發展的手提式平板電腦由於擁有比PDA更大螢幕的特性因此具備在醫學影像判讀上佔一席之地的可能性。運用這種概念，我們嘗試利用在腹部X光片上評估臨床常見的尿路結石，以ROC曲線比較使用平板電腦與在影像儲存與傳輸系統工作站（PACS）上對結石的判讀有無明顯不同。結果發現兩組數據並無統計上有意義的差異。本次小規模研究的結果支持平板電腦在某些臨床應用上其診斷準確度可比拟正常使用之高解析度螢幕。

關鍵詞：微電腦；影像資訊系統