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The last two years have demonstrated an exponential growth in the use of smartphones and tablets by medical professionals, a trend that has led to medical apps developed specifically for patients and physicians.¹⁻⁷ Not surprisingly, because most app developers are unverified sources of medical information, recent publications have emphasized the importance of peer-review validation.⁷⁻¹⁰ In addition to safety concerns, the validation of mobile apps in the health care setting provides an opportunity for younger physicians, often medical students and residents, to contribute to the medical community by demonstrating the efficacy and validity of these new technologies. However, many trainees and practicing physicians are unfamiliar with scientific validation methodology. This editorial outlines a structure that can be used to assist with the design, execution, and publication of a validation study for mobile technology.

Validation refers to proving a tool’s ability to report the absolute “truth” as much as it can be measured. Various forms of validity exist that, when combined, allow a tool to be considered “valid” by the medical community. To clarify various forms of validation, I will share examples from the current literature, which can serve as guides for providers interested in designing a study of their own.

**Types of Validation**

Before embarking on a validation study, one must possess a clear understanding of the gold standard against which your new tool or app will be validated. A literature search should reveal the existing standard. If not easily identified, consult with a colleague or professional in your field to guide you.

**Criterion Validity**

Once the gold standard has been selected, criterion validity is the method used to demonstrate a direct correlation between the new tool and existing standard using an appropriate statistical test, such as a Pearson correlation. Consider one study that validated the use an Android smartphone for gait analysis and confirmed criterion-validity by evaluating the correlation between the gait parameters obtained by the smartphone and the gold standard, a tri-axial accelerometer. The statistical test they used was Spearman’s correlation coefficient r.¹¹ Their results demonstrated a correlation between the smartphone and the goniometer ranging from 0.82-0.99, suggesting a strong relationship and thereby confirming their criterion validity.¹¹

**Construct Validity**

Construct validity is another form of validity, and refers to the systematic change in results when the input variable is under varying conditions.¹² More specifically, it answers the question, ‘does the new tool do what it is supposed to do?’ In contrast to a comparison against an existing standard, construct validity aims to demonstrate an appropriate response against a real-world measure. For example, a recent study validating a virtual reality simulator for robotic surgical skills demonstrated construct validity by correlating outcomes using the device with each participant’s level of robotic surgery experience.¹³ By demonstrating that experience correlated with their simulator skills, construct validity was established. Importantly, while a tool may not meet criterion validity (it may not measure the desired outcome very accurately), it could still meet construct validity (fulfilling the predicted effect). For these types of comparisons, analysis of variance (ANOVA) is often used to reveal the effect of a single variable when multiple variables are being tested.
Intra-observer Reliability
A third statistical characteristic is intra-observer reliability, also known as test-retest reliability, which reflects a highly-reproducible outcome when tested under constant conditions by the same observer. From a clinical perspective, this implies that results should remain the same when testing conditions are unchanged. For example, one study examined intra-observer reliability when utilizing a smartphone to assess shoulder range of motion by testing 41 subjects twice, with a 30-minute interval between tests. The intraclass correlation coefficient (ICC) was the statistical test used to compare results at the two testing points and revealed a high degree of correlation for each observer, thus confirming intra-observer reliability.

Inter-observer Reliability
Similarly, inter-observer reliability, also known as inter-rater reliability, reflects the accuracy and precision of a tool when used by various care providers. For example, a new device would not be particularly useful if only the developer could use it properly. Thus, it is important to prove that a tool can be equally effective with a basic level of training for different providers. Using the same example as above, the authors also examined inter-observer reliability by testing 3 different providers using the device on the same group of patients. Once again, ICC was used to compare the results and revealed a strong correlation.

Content Analysis
In addition to the statistical validation techniques described above, the content of information provided in apps can be verified by performing a content analysis. In this way, the data within an app is compared to a reliable source, such as a gold standard textbook or guideline. One study performed a content analysis on 47 apps that were advertised to assist with smoking cessation and were evaluated based on their adherence to the U.S. Public Health Service’s 2008 Clinical Practice Guideline for Treating Tobacco Use and Dependence. From their analysis, they were able to rate the apps with respect to adherence to the published guidelines.

Study Design and Analysis
Once the validation tests and techniques are understood, you can determine the study methodology. Importantly: are patients required for you to validate your tool? If so, an ethics committee or institutional review board (IRB) must approve your protocol. Keep in mind, however, that many institutional review boards offer an accelerated application for projects that present little risk to subjects. The IRB process includes thinking about patient recruitment, which is often the time-limiting step for a study. Ask colleagues for help, advice, and ideas if you anticipate this will be a challenge. Lastly, focus on how you will collect your data. What data will you collect? How will it be collected and how will the results be stored? Who is collecting the data and who is analyzing it? Will the process be blinded? A great amount of time can be saved by carefully outlining the research plan.

After the plan has been outlined and an IRB application has been approved, data collection should proceed smoothly and efficiently. A trial data collection period will help identify any potential methodological limitations planned in the study. In other words: do not expect your first trials to produce usable data; your measurement techniques are likely to change significantly within the first 5-10% of data collection.

Once collected, data must be analyzed. Statistical analysis intimidates many researchers who are unfamiliar with these tests. If this is true, ask a friend or colleague to help. As outlined above, the general principles for validating new tools do not require particularly difficult statistical tests and can usually be completed after only 1 or 2 meetings with a knowledgeable colleague.

Manuscript Preparation and Submission
The final step is manuscript preparation. They key to writing a compelling and interesting manuscript is allowing the data to drive the study’s conclusions in the context of the aims and hypothesis that were set out from the start. Avoid the temptation of trying to fit the data to your conclusion. Rather, recognize that all scientists embark on studies to either confirm, or refute a theory, but it is the unpredictable nature of science that appeals to so many researchers. Examine the data with an open mind, share it with colleagues, and let your results guide your conclusions without bias.

The conventional scientific paper format for nearly all journals is: Introduction/Background, Aims/Hypothesis, Methods, Results, Discussion, and Conclusions. However, the order of preparing each section should not necessarily follow the order of formatting. Rather, a manuscript should typically be written in the following order: figures, results, methods, and discussion, with the introduction written last. Following this sequence most closely represents the intellectual progression of an experiment and can help organize the author’s thoughts. The data (figures...
and results) are reported, the methods are confirmed, and the implications are discussed and supported. Only after a study is completed can an appropriate introduction be written. This step can potentially save hours of revision time.

After reviewing and improving the manuscript, submission to an appropriate journal should not be delayed. Selecting the proper journal also requires care, and important factors to consider include a journal’s primary focus, the breadth of readership, publication format (online or print), indexing databases, impact factor, publication costs, copyright ownership, and duration of peer review.

Conclusion
In addition to the many examples described above, there are a number of other good validation studies that can help guide the design of future studies. I would encourage interested readers to read more about a smartphone heart rate acquisition application, an evidence-based application for treating cervical spine trauma, validation of heart rate extraction using an iPhone accelerometer, validation of a Timed Up and Go test, using smartphones to measure Cobb angles in scoliosis, and improving total hip arthroplasty component placement with a smartphone.

While the editors of the jMTM take pride in our rapid manuscript review process (often less than 1 month), most journals will take anywhere from 3-6 months (or longer) for the first round of peer-review. As the lead app editor of jMTM, I look forward to reviewing your studies about mobile applications in healthcare.

References
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Principles of Security for the use of Mobile Technology in Medicine

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The rapid uptake of mobile technologies has allowed a number of innovations in the medical field1,2. However, as with any new technology, there are a number of security concerns that need to be acknowledged and addressed in order for these technologies to be implemented safely3. This is of particular significance in the medical realm where confidentiality of patient data needs to be preserved. Whilst data security is considered a more sensitive topic with evolving technologies, it is important to also consider the security benefits provided by mobile technologies.

Portability is one of the hallmark features to mobile technologies, allowing rapid access to information at convenience to the clinician. Unfortunately this too represents one of the greatest security risks, as each mobile device can carry large amounts of patient data, and have access to further sensitive information. In the past, should a clinician lose a briefcase with paper files, whilst disastrous, only the information stored within the briefcase would be lost. With the loss of a mobile device, this could represent potential access to large amounts of patient data. An interesting study conducted by Symantec® in 20124 called “Project Honey Stick”, showed some fascinating insights into data accessed on an unsecured lost smartphone. They characterised this by placing 47 unsecured smartphones in the public, and ran special software on the smartphones which would track the use of these devices. Key findings from there study included:

- 89% of devices were accessed for personal related apps and information
- 83% of devices were accessed for business related apps and information
- 70% of devices were accessed for both business and personal related apps and information
- 45% attempted to access corporate email

The first and most important safeguard to this situation is to have a passcode enabled. Depending on the operating system of your mobile device, this can be in the form of a 4 digit pin, a pattern or an alphanumeric password. To maximise the protection offered by this passcode, it is recommended that a regular alphanumeric passcode be enabled, rather than a simple 4 digit PIN, (which can also be enabled on iOS devices http://goo.gl/Zdsxk). Furthermore, features such as “Erase data after 10 failed passcode attempts” are strongly recommended to further protect data. With regular backups in place, the inconvenience of having one’s device wiped is far outweighed by the inconvenience of all data on one’s mobile device being revealed.

The second step is to enable data encryption, which is enabled by default on all recent iOS devices with a passcode5. Blackberry® devices, and most newer Android devices are also being capable of this, though the details would need to be confirmed with your particular device. Data encryption helps protect against instances when devices fall into the hands of those with technical expertise. Rather than guessing the passcode, one who wishes to access your data can manually offload the contents of the device onto a computer, and then can try to access this data directly, bypassing the mobile device itself. If the device is encrypted, then this data needs to be first manually decrypted before it can be accessed. If the device’s data is only secured with a simple 4 digit passcode,
this process takes minutes using a “bruteforce” attack, whereas a secure alphanumeric passcode could take days, months or years to bypass. Presently, this type of attack has been confirmed to work on iOS devices before the iPhone 4S and iPad 2, however it is only a matter of time before newer devices also become susceptible.

Another strategy to limit data loss in the event of device loss is to simply not have any data on the device itself. Applications can be constructed for mobile devices such that the device only acts as a portal of interaction to a central cloud based server which stores the data itself. The application itself would need to be secured with a secure password to prevent unauthorised access, however this eliminates a number of security concerns, as no patient data is stored on the device itself. An example of such use is the Citrix Receiver®, which is discussed in greater detail in a separate article in this issue of the Journal of Mobile Technology in Medicine.

Direct attacks on mobile devices from “viruses” and “malware” are far less common than previously experienced on traditional desktop computers due to a number of reasons. For example, on the iOS platform, applications can only be downloaded and installed through a curated “App store”, and this certainly helps reduce the chances of installing programs with unsavoury intentions. Other devices where applications can be installed without going through this vetting process are more vulnerable. For example, the first malicious program for smartphones was reported by Kaspersky Labs® in 2010, named “Trojan-SMS.AndroidOS.FakePlayer.a”9. This was a virus that sent SMS’s to premium rate numbers without the owners consent. Maintaining the latest version of the operating system of your device ensures that you are up to date with the latest security patches and is an essential part of mobile security. It is important to note that this is an area of concern for some mobile operating systems where there is much fragmentation of devices, and as such some devices may not receive updates as frequently as other devices.

There are also key advantages to mobile devices. The ability to remotely locate and wipe devices is invaluable in mobile technologies, and it is strongly recommended that all mobile devices used for medical purposes need this capability. This is increasingly becoming a standard feature in many mobile platforms. Remote location functionality of devices allows tracking using the data and GPS functionality to show the real-time location of a mobile device, potentially allowing for recovery. Remote wiping works on a similar principle, but rather sends out a command to the device to destroy all data on the device, thus preventing unauthorised access to the data residing on the device. The disadvantage of these features is the requirement for the mobile device to have internet connectivity. Whilst portability is a key security concern, this also confers advantages. Desktop computers are typically left on in hospitals and anyone walking past can utilise an unsecured terminal and peruse confidential patient data. Whilst password protections are in place, in practice, I have personally seen many unattended computers with pathology and radiology viewers running unsecured. With portable mobile device, there is a tendency to carry these on your person, thus reducing the chances for access by third parties.

As with all evolving technologies, data security is an area that must be addressed in order for safe implementation of mobile technology. Currently there are no formal guidelines from regulatory bodies governing security in mobile devices, and as such one needs to be aware of these issues. Whilst mobile devices present a number of potential vulnerabilities, the greatest arising from their portability, there are a number of methods of overcoming such concerns. Previously, the loss of a paper file was irreversible, however with newer technologies, the loss of a mobile device need not represent a catastrophic event if adequate measures are in place.

References
6. Greenberg A. Here's how Law Enforcement Cracks your iPhone [Internet]. Forbes. 2012 [accessed

Introduction
With the advent of mobile technology, the interface in which the clinician can view medical imaging and electronic records is more accessible than ever. The Citrix Receiver™ provides a secure platform for clinicians to access a virtual desktop, linked to the hospital server, via their mobile tablet device or laptop computer. This technology was born out of the need for mobile offices dedicated for the clinician, and has since been adopted by medical professionals in many centres as a means for offsite access to hospital electronic medical records (EMR). With the nascent boom of health informatics and ‘tele-medicine’ due to the birth of mobile devices, we are continuously in the pursuit towards improving the efficacy and timeliness of healthcare delivery as well as ensuring patient safety. Citrix Receiver™ is but one example and it is currently in use amongst the Orthopaedic registrars at the Austin Hospital in metropolitan Melbourne, Victoria.

The Citrix Receiver™ is a user-friendly client software that is installed on a portable device, which provides a secure, encrypted connection between the clinician and the hospital server to provide remote access to a “virtual desktop”. This allows hospital documents and applications to be securely accessed from a mobile tablet device (iPad or android) or laptop computer (PC or Mac). Therefore, the Citrix Receiver™ provides virtual access to the hospital’s network. The Hospital Administrators and Information Technology Departments control the content of this virtual desktop, including links to the medical imaging software (New AGFA Web 1000™) and Scanned Medical Records in addition to access to the hospital intranet.

Once a clinician has received clearance for access from their administrator, one simply downloads the Citrix Receiver™ from the product website (http://www.citrix.com/English/ss/downloads/index.asp) or relevant tablet application download site (e.g. iTunes, 13.6 megabytes). On first log-in, the clinician must enter in the unique account settings including: address of the host server; username and password; and domain name. The clinician’s individualized hospital log-in details would then allow access to the virtual desktop, granting use of scanned medical records and other useful accompanying features (Figure 1). There are few issues with compatibility as the applications are loaded and run via secure, centrally located server, which is the hospital server itself, and not through the user’s mobile device.

Figure 1: Citrix Login Screen on an Apple iPad

Strengths
The convenience of using mobile technology to access medical records and imaging cannot be denied. A recent cross-sectional survey by physicians in North America elucidated that the increasing use of mobile
technology amongst specialty physicians was a predictor of career satisfaction\(^2\). This can be further extrapolated by the uses of health information technology (HIT) in the figure below (Figure 2- taken from the same study), as various means of complementing the clinician’s practice.

![Image of chart showing Use of Health Information Technology (HIT) by Physician Type]

**Figure 2:** Use of Health Information Technology by Physician Type

For the on-call Orthopaedic registrar, being able to review imaging and case notes from home is invaluable. Previously, one would have to rely on verbal descriptions of images from the referring doctor, or travel to hospital to review the films in person\(^3,4\). With remote access technology, the Citrix Receiver™ facilitates timely referrals and decision making on the part of the specialty registrar. (An example of this imaging can be seen in Figure 3.)

![Image of off-site access to hospital radiology]

**Figure 3:** Off-Site access to hospital radiology

With the advent of Multimedia Messaging Services (MMS) on mobile phones, where images can be shared using mobile-to-mobile phone technology, the Citrix Receiver™ for iPad proves its superiority with a larger screen and higher resolution\(^5\). Nevertheless, a recent study by Padmasekara et al. examining the reliability of MMS compared to the standard computer monitor for the decision making of distal radial fractures have revealed no significant difference between the two modalities\(^6\). Studies similar to this are a testament to the utility of mobile devices such as the iPad in tele-radiology.

Even when a clinician is onsite at their hospital, access to the Citrix Receiver™ via a tablet device provides quick, mobile and easy access to electronic patient records\(^7\). This is particularly useful on daily ward rounds and the concomitant laborious tasks such as reviewing pre- and post-operative imaging and checking recent blood test results. Overseas, the Louisiana State University Health Sciences Centre (a large tertiary hospital) has piloted the use of personal digital assistants (PDA) in their oncology ward rounds to aid in their ward rounds. Their experience is a positive one in that the use of PDAs has reduced their clinical workload as well as ensuring evidenced-based care and patient safety through the ready-access of pharmaceutical guidelines and patient blood results. In our experience, the use of Citrix Receiver™ expedites the whole ward-round process in order to decide on a management plan early in the day. This is particularly pertinent in areas of the hospital (e.g. operating suite, wards, doctors’ office) where there is a shortage of desktop computers to access records.

Wherever mobile technology is used to access confidential records, maintaining security of those records are of utmost priority\(^8,9\). Patient confidentiality is maintained by password access to the applications on the Citrix Receiver™ desktop. A secure network is utilized. The automatic lockout time from an idle application is approximately five minutes, which is useful in the case of forgetting to close applications, but this can also be frustrating when using the application for other complex purposes such as preparing for multi-disciplinary meetings and case reviews. Furthermore, an added level of security is ensured in that a unit administrator must approve for a staff member to have remote access to the server.

**Pitfalls**

The Citrix Receiver™ application can be onerous at times. In our experience, the loading time of various applications can vary significantly to the extent that the system would log the user offline. This phenomenon has been anecdotally tested on several mobile devices as well as computers and the problem appears in all of them. This may reflect problems with the hospital server, network or hardware. Other
common errors include the screen spontaneously turning to black when using the application on the iPhone as well as network connection failures with the iPad.

Furthermore, the use of Citrix Receiver™ requires the purchase of a personal mobile device, which is not funded by the hospital. Therefore, the clinician has to pay for the convenience of having remote access to a personal tablet or laptop computer and for the internet connection. These costs may be mitigated by the ability to claim these costs on the annual tax return.

It could be postulated that remote access to records and imaging could actually result in patient harm. By developing a treatment plan over the phone, based solely on imaging and a verbal report from a non-specialty doctor, the Orthopaedic registrar runs the risk of becoming a “radiologist” – basing decision making on imaging and not clinical assessment. In addition, these “radiological-based decisions” are often made in the middle of the night, with the registrar not fully alert. The natural corollary to this is a sub-optimal clinical decision that may lead to patient harm.

Also, one could argue that by having remote access to imaging and blood test results, an expectation could form that the clinician should and will be checking the results at home, after the working day. So conversely, this application, which is designed to facilitate work/life balance, has the potential to have a paradoxical negative effect on that very balance.

**Conclusion**

The Citrix Receiver™ for mobile tablet devices and laptop computers provides secure, remote access to a virtual desktop linked to the hospital server. The convenience of accessing work applications from anywhere cannot be denied, however it has the potential to blur the lines between work and home life. For the on-call registrar, it is a vital tool when receiving referrals without the need to be physically present at hospital. Although the occasional technical malfunction does occur, this application is easy to download and use. Overall, the Citrix Receiver™ provides a useful and meaningful adjunct to clinical medicine and surgery.

**References**


Mobile Technology Usage by Orthopaedic Surgeons and Trainees in Australia

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Background: The use of smartphones and portable tablet devices is increasingly more common and widespread in Australia. Usage amongst medical professionals is increasing in a number of fields. The purpose of this study was to gain insight into the current and future usage of these devices by orthopaedic surgeons and orthopaedic trainees, in addition to understanding the perceived impact on patient care.

Methods: A survey examining mobile technology usage was administered via email to a number of orthopaedic surgeons and trainees across Australia. Data regarding the respondents’ ownership and usage of mobile technology, perceived future usage, and impact on patient care and productivity was collected and analysed.

Results: 97.7% of respondents currently use a smartphone, and 58.1% use a tablet device. The most common work use was for professional contact (78%), viewing journals, online educational resources (68.3%), and viewing radiology (46.3%). Respondents showed a significant interest in the ability to view x-rays and computed tomography (CT) in the future. Overall, surgeons indicated that mobile technology improves patient care and productivity, and they believe they will use it more often in the future.

Conclusion: Mobile technology usage is highly prevalent amongst orthopaedic surgeons and trainees in Australia. These technologies may be used to facilitate improved quality and timely provision of care.

Introduction

Mobile technology usage, particularly the use of smartphones and tablets, has increased greatly amongst the general public in Australia in recent years. Smartphones have a number of features including speed, simplistic interface, integrated communications, which make them a valid alternative to a tradition desktop computer. Tablet devices like the iPad (Apple Computer, Cupertino California) have been described as portable medical libraries.

Smartphone usage amongst doctors, and surgical trainees has previously been investigated, but the specific usage by orthopaedic surgeons in Australia has not been fully investigated.

These mobile devices provide several different functions for users. The most common of these are the ability to send and receive text, multimedia or picture messages; send and receive emails; browse the Internet and use specific applications (apps). These functions together or separately provide surgeons with additional tools to aid in clinical practice.

Some clinical applications of smartphone usage in orthopaedic surgery have previously been examined, and shown to have potential for timely and cost effective management of orthopaedic patients.
We sought to further delineate the usage patterns and preferences of mobile technology use amongst the orthopaedic profession in Australia.

**Materials and Methods**

Data collection for this study was performed via a survey of orthopaedic surgeons and registrars in Australia. An online, digital survey was developed to question participants regarding their level of training, smartphone and tablet ownership, current and future intended usage, and perceived impact on productivity and patient care. A free response section was included to allow respondents to add further comment to their experiences.

The survey was designed to be brief, and was planned in line with previously published recommendations to improve response rate amongst orthopaedic surgeons.

The survey was distributed by email, with an explanation provided regarding the purpose of the survey. In addition respondents were encouraged to forward the survey on to other orthopaedic surgeons and registrars. Completion of the survey acted as consent. All responses were anonymous, and data was kept securely.

Some basic demographic information surrounding age and level of training was collected. The respondents answered a number of questions regarding their current and possible future implementation of these devices, and the perceived impact on patient care and productivity.

Responses were collated and entered into a Microsoft Excel (2010) spreadsheet. Descriptive statistical analyses were then performed to ascertain percentage responses to each question.

**Results**

A total of 92 total responses were received, comprised 22 orthopaedic registrars, 4 orthopaedic fellows and 66 orthopaedic consultant surgeons. The majority of recipients were between the ages of 28 and 40 (Table 1).

<table>
<thead>
<tr>
<th>Respondent Age</th>
<th>Response percent</th>
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<tbody>
<tr>
<td>23-27</td>
<td>0%</td>
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<tr>
<td>28-34</td>
<td>30.4%</td>
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<tr>
<td>35-40</td>
<td>23.9%</td>
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<td>41-50</td>
<td>28.3%</td>
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<tr>
<td>51-59</td>
<td>8.7%</td>
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<tr>
<td>60 or older</td>
<td>8.7%</td>
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<table>
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<th>Orthopaedic experience</th>
<th>Response percent</th>
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<td>Registrar</td>
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</tr>
<tr>
<td>Fellow</td>
<td>4.3%</td>
</tr>
<tr>
<td>Consultant</td>
<td>71.7%</td>
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</table>

Table 1: Demographics of respondents

Over 97% of respondents owned a smartphone, and 56% owned a portable tablet device. Of these, all but two used their devices regularly for work.

The main uses for mobile technology in clinical orthopaedic practice are for professional contact, i.e. with other doctors and surgeons (79%), and for accessing journal articles and other educational resources online (65.1%).

When the respondents were questioned on which specific features of mobile technology they would like to use in the future, the ability to view x-rays and other radiology imaging on their device was most desired (86%). A majority also intended or would like to view journals or online resources (65%), or use their device for practice management (63%) and the viewing and entering of medical records (63%).

Those answering the survey were asked about their use of text or multimedia messaging services (MMS) and email. Use of these modalities for professional contact (93% text/MMS; 86% email) was popular, as was sending and receiving clinical photographs and x-rays/radiology images (76%; 76%).

When questioned about how various facets of mobile technology impact on productivity, a large number of respondents indicated these technologies increased productivity (Table 2). Most respondents identified viewing patient investigations and accessing patient records as the most productive purpose for mobile phone use in orthopaedic practice.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Less Productive</th>
<th>No Change</th>
<th>More Productive</th>
<th>Unsure</th>
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</thead>
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<td>Viewing Radiology</td>
<td>4.8%</td>
<td>7.1%</td>
<td>83.3%</td>
<td>4.8%</td>
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<td>Viewing test results</td>
<td>2.4%</td>
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<td>69.0%</td>
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<td>Accessing medical records</td>
<td>2.4%</td>
<td>16.7%</td>
<td>71.4%</td>
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<td>Patient progress tracking / functional scores</td>
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<td>16.7%</td>
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<td>Accessing textbooks</td>
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<td>Patient contact</td>
<td>2.4%</td>
<td>47.6%</td>
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Table 2: The effect of accessing or using specific resources on productivity

<table>
<thead>
<tr>
<th>Activity</th>
<th>Lower Standard of Care</th>
<th>No Difference</th>
<th>Higher Standard of Care</th>
<th>Unsure</th>
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<tr>
<td>Practice / database management</td>
<td>0%</td>
<td>38.1%</td>
<td>52.4%</td>
<td>9.5%</td>
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<tr>
<td>Patient progress tracking / functional scores</td>
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<td>42.9%</td>
<td>50.0%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Accessing textbooks</td>
<td>0%</td>
<td>35.7%</td>
<td>57.1%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Accessing journal articles / online resources</td>
<td>0%</td>
<td>35.7%</td>
<td>61.9%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Professional contact</td>
<td>0%</td>
<td>33.3%</td>
<td>64.3%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Patient contact</td>
<td>2.4%</td>
<td>39.0%</td>
<td>39.0%</td>
<td>19.5%</td>
</tr>
</tbody>
</table>

Table 3: The effect of accessing or using specific resources on patient care

<table>
<thead>
<tr>
<th>Activity</th>
<th>Reduces</th>
<th>Neutral</th>
<th>Improves</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timely provision of care</td>
<td>0.0%</td>
<td>19.0%</td>
<td>78.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Patient follow up</td>
<td>2.4%</td>
<td>42.9%</td>
<td>52.3%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Practice management</td>
<td>0.0%</td>
<td>16.7%</td>
<td>71.4%</td>
<td>11.9%</td>
</tr>
<tr>
<td>Ongoing education</td>
<td>0.0%</td>
<td>11.9%</td>
<td>85.7%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Professional communication</td>
<td>0.0%</td>
<td>4.8%</td>
<td>92.8%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Patient Communication</td>
<td>2.4%</td>
<td>39.0%</td>
<td>48.8%</td>
<td>9.8%</td>
</tr>
<tr>
<td>Overall patient care</td>
<td>0.0%</td>
<td>14.3%</td>
<td>85.7%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table 4: Effect of mobile technology on different aspects of clinical orthopaedics
The majority of respondents believe that the use of smartphones has a beneficial impact on patient care (Table 3). Results from Table 3 highlighted that most respondents believed accessing investigations was associated with a higher standard of patient care.

Additionally, when questioned about the effect of mobile technology on several areas of clinical orthopaedics, responses showed almost no perceived negative effects (Table 4). The use of mobile phones for professional contact featured highly amongst orthopaedic trainees and surgeons, and 93% identified that mobile technology improved professional communication. Importantly, 86% believed that the effects of mobile technology in clinical practice would improve patient care.

Overall most orthopaedic surgeons and registrars indicated that they were likely to use mobile technology more in the future (86%) (Figure 1). The majority also replied that overall mobile technology improves the level of patient care (83%). (Figure 2)

### Figure 1

- **I will use it more (86%)**
- **I will use it the same amount (14%)**

### Figure 2

- **83% - Improves level of care**
- **14% - No Change**
- **2% - Reduces Level of Care**

### Discussion

Smartphones and tablet devices have had a profound effect on the access and transmission of information, and their use is continually increasing. The medical world has often been at the forefront of the development and implementation of new technology. This study highlights the exceptionally high usage rates of these technologies by orthopaedic surgeons and registrars.

One interesting aspect is the wish to use apps to view radiology on smartphones and tablet devices. Currently there are no specific apps available in Australia that allow direct access to radiology picture archiving and communication systems (PACS). Currently the common implementation of offsite radiology is to use a Citrix based system to have access to the hospital computer network. However, Synapse (FujiFilm, Tokyo, Japan) has a mobile app available (Synapse Mobility) to connect to institutions running their Synapse PACS. At time of research, this app was not operational in Australia. Concern was raised by several respondents of the study about the resolution of screens and possible medico-legal issues arising from this. However respondents indicated that the ability to view imaging gave the ability to initiate timely treatment.

The survey results addressing the impact of mobile technology on productivity and the impact on patient care were almost universally positive. This provides
an indication that the orthopaedic community see these devices as key to the timely provision of both clinical treatment and administrative duties, and their effect is positive both for the clinician and patient. It was interesting to note the only area that respondents felt mobile technology may not be helpful was in patient contact. This is understandable, as most clinicians prefer to interact in person with their patients.

The majority of orthopaedic surgeons and trainees foresee that the use of mobile technology will increase in orthopaedics. This presents a great opportunity for developers of apps for these devices to target the orthopaedic community. Previous research has shown that orthopaedic surgeons are highly willing to pay for high-quality apps. In addition to this, hospitals need to be cognizant of the increasing use of mobile technology by clinicians. A concerted effort should be made to integrate mobile technology into the existing systems available.

This study does have some limitations. It consisted of a novel, non-validated survey that was distributed to and amongst orthopaedic surgeons and trainees. The 92 responses received may not necessarily be representative of the 1,362 current members of the Australian Orthopaedic Association. By using a survey that was delivered by email, and completed digitally, bias may be introduced when surveying about technology. Future studies comparing the use of mobile phone technology amongst other subspecialties would provide interesting insights into the relevance of mobile-based applications across surgical and non-surgical specialties. This information could guide the use of more relevant applications for each specialty.

Conclusion

It is apparent from this study that use of smartphones and tablets in orthopaedics is already widespread in Australia. They are already an important tool for communication, professional development, productivity and patient care. Clinicians believe that their effect is positive on productivity and patient care, and that their use will increase in coming years.

References


Appendices

PDF of Survey

Accuracy of Mobile Phone Pedometer Technology

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Corresponding Author: boyce_glenn@hotmail.com

Background: Moderate to high intensity activity is an important component in weight loss. The ability to use free technology to monitor activity would provide a useful clinical tool.

Methods: Three popular pedometer mobile applications (“iSteps Lite”, “Pedometer Lite” and “Lyr Free”) were compared to a conventional pedometer. Outcome measures included step recording, speed estimate, distance recorded over a fixed distance and steps recorded during car travel.

Results: All devices show inaccuracy in step count and speed estimate at varying intensities of activity. For measurement of 100 steps at medium intensity activity, the range of recorded step counts detected at medium sensitivity was 69.3 to 101.3. Valid and reliable results for step count were seen with the control pedometer and with one program at moderate sensitivity settings for moderate and high intensity activity. The most accurate distance recorded and estimate of speed over a fixed distance was from a program with Global Positioning System (GPS) functionality.

Conclusion: It is possible to determine a step count as accurate as a control pedometer with careful selection of program and calibration. When exercising over a distance, a program with GPS functionality leads to the most accurate determination of speed estimate and distance recorded.

Key words: Pedometer, Accuracy, Mobile Phone, Weight Loss, Technology, Software
most interest to clinicians, pedometers can be useful clinical tools.

Recently, with the development of more sophisticated mobile phone technology (‘smart phones’), many commercially available phones are now equipped with a built in accelerometer, which can be utilized by pedometer applications, which are able to be downloaded from the internet. Hence, there is now potential for a patient’s own mobile phone to be used as a ‘pedometer’ for exercise intensity monitoring purposes. This may mean the ability for medical practitioners to monitor compliance with exercise advice may be simplified, and may only involve downloading an application onto a patient’s mobile phone. Furthermore, many pedometer applications allow adjustment of individual user characteristics and sensitivity levels, whilst others can utilize Global Positioning (GPS) technology, all of which may improve accuracy when compared to conventional commercially available pedometer devices.

We conducted a prospective observational study which aimed to investigate the accuracy of the most popular free of charge pedometer applications available for download to mobile phones equipped with an accelerometer. We hypothesized that the accuracy of pedometer applications easily available for download to ‘smart phones’ would be comparable to traditional pedometer devices.

**Methods**

An internet search for all free pedometer applications was conducted on an iPhone 4 mobile phone device (Apple Corporation, Cupertino, CA) using the standard ‘App Store’ application included on the phone. Inclusion criteria for pedometer applications were:

1. The program should be free of charge indefinitely after download. Applications with a free trial period of finite length were not included.

2. The program should have full and efficient functionality after downloading, without additional software download being necessary.

3. The application must record the number of steps taken, average speed and total distance.

4. The applications must have the functionality to record and upload exercise data to a computer.

5. The applications must have adjustable sensitivity settings.

The selected pedometer applications were compared to a Yamax Digi-Walker SW-700/701 pedometer (Yamasa Tokei Keiki Co. Ltd., Tokyo, Japan) as a control. The control device was used in conjunction with an electronic stopwatch to allow speed and distance calculations to be made. An iPhone case with belt clip was used to secure the iPhone beside the Pedometer on the waistband.

The pedometer applications were tested for their ability to record the number of steps taken on a treadmill set at 3, 6 and 9km/h speed settings, with the program set at its minimum, medium and then maximum sensitivity settings (0, 50%, 100%). If the program was able to self calibrate, a further recording would be taken at each speed after calibration. The programs were then further tested for their accuracy over a 1km distance and over a pre-planned route, with the application set at medium sensitivity. This would allow programs with GPS functionality to improve accuracy. Finally the amount of steps recorded during a 1km car trip was recorded at variable sensitivity settings, to estimate the degree of possible confounding due to background movement.

A single subject and a single observer were used for all the trials. Relevant characteristics such as height (165cm), weight (59kg), gender (female) and stride length were into entered each program. Stride length was measured as 60cm at 3km/h, 75cm at 6km/h and 1m at 9km/h.

Statistical analysis was performed using MedCalc Version 12 (MedCalc Software, Belgium). A result would be deemed valid if the step count was within 20 steps of the actual count. For a speed measure the result would be valid if the speed was within 0.5 km/hr of the actual speed. A result for step count or speed would be deemed reliable if the relative standard deviation of results was less than 1%. Strength of agreement was evaluated through concordance correlation coefficients (pc) where less than 0.90 was deemed poor; 0.90 to 0.95 moderate; 0.95 to 0.99 substantial; and greater than 0.99 to be perfect. Student’s t-tests were conducted to compare the means of step counts, speed and distance measurements of the pedometer applications with the control pedometer. A significance value of <0.05 was considered statistically significant.

**Results**

Ninety results were returned when conducting a search using the search terms ‘pedometer’ and ‘free’ on the iPhone 4 ‘App Store’ application. Fifty-five of these reported functionality as a pedometer or accelerometer, but only three applications met all
inclusion criteria. The most common reasons for exclusion was the inability to record or upload activity data, inability to adjust sensitivity, or significant functional restriction placed on free versions of the software.

The final three pedometer applications included were:

**iStepsPLite Petar Dinev, [http://pdinev.blogspot.com/](http://pdinev.blogspot.com/):** Calculates distance based on entered stride length, average speed, calorie expenditure and number of steps taken. Application data is formulated independently of GPS function, sensitivity is adjustable, and data can be recorded and downloaded to a computer. This application also features music player and map linking functions (Figure 1).

**Pedometer Lite (Luminant Software, [http://luminantsoftware.com/](http://luminantsoftware.com/)):** Calculates distance based on preset stride length for a participant's height, average speed, calorie expenditure and number of steps taken. This application has self calibration capability, able to track distance using inbuilt GPS, has adjustable sensitivity and can record and download exercise data. This application also has music player functionality (Figure 2).

**LYR Free (LogYourRun.com):** Calculates distance using GPS function alone. This application utilizes the phone accelerometer to calculate steps taken when the GPS signal is weak or when the subject is not moving in relation to the GPS satellite, for example when exercising on a treadmill. In these circumstances, the application calculates distance travelled, speed and calorific expenditure based on multiplying the number of steps recorded by a pre-entered stride length. This program offers online support, offers maps which may be downloaded from the internet and provides trip information statistics. Adjustable sensitivity settings, ability to record and download exercise history data and music player functionality are also provided (Figure 3).
### Table 1: Summary of data from trials with 100 steps at 3km/hr

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>Sensitivity</th>
<th>Steps Recorded (100 Steps)</th>
<th></th>
<th>Speed Recorded</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Relative SD (%)</td>
<td>Validity</td>
<td>Reliability</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>69.3</td>
<td>30.5</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>iStepsP Lite</td>
<td>Low</td>
<td>30</td>
<td>29.1</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>36.7</td>
<td>12.9</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>149.7</td>
<td>10.4</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Pedometer Lite</td>
<td>Low</td>
<td>16.7</td>
<td>120.7</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>113.3</td>
<td>4.1</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Self calibrated</td>
<td>87.7</td>
<td>0.7</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>LyrFree</td>
<td>Low</td>
<td>20.3</td>
<td>10.2</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>40.3</td>
<td>14.1</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>70.7</td>
<td>3.0</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

### Table 2: Summary of data from trials with 100 steps at 6km/hr

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>Sensitivity</th>
<th>Steps Recorded (100 Steps)</th>
<th></th>
<th>Speed Recorded</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Relative SD (%)</td>
<td>Validity</td>
<td>Reliability</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>101</td>
<td>2.0</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>iStepsP Lite</td>
<td>Low</td>
<td>81.7</td>
<td>7.1</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>101.3</td>
<td>1.5</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>185</td>
<td>3.8</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Pedometer Lite</td>
<td>Low</td>
<td>8.3</td>
<td>79.9</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>69.3</td>
<td>1.7</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>127.7</td>
<td>8.8</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Self calibrated</td>
<td>87.7</td>
<td>2.6</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>LyrFree</td>
<td>Low</td>
<td>66.3</td>
<td>5.7</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>80.7</td>
<td>2.6</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>90.3</td>
<td>7.4</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
The control pedometer had a relative standard deviation (SD) of 30.5% and 31.5% and was not found to have validity or reliability. The pedometer applications were also inaccurate, with none of the applications found to be both valid and reliable for both speed estimate and step count.

At medium speed (6km/h) the control pedometer was found to be accurate in determining number of steps and speed, with only a relative SD of 2.0% for calculating step count, and 0.6% for calculating speed. (Table 2). iStepsP Lite at the medium sensitivity setting, and the Pedometer Lite at the self-calibrated setting were found to be both valid and reliable at recording number of steps and average speed at 6km/h.

At high speed (9km/hr), the control pedometer was found to be valid and reliable again, with a relative SD of 0.6% for steps recorded and 1.3% for average speed. The only pedometer application to be reliable and valid at this speed was the iStepsP Lite at the medium sensitivity setting. (Table 3)

Table 3: Summary of data from trials with 100 steps at 9km/hr

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>Sensitivity</th>
<th>Steps Recorded (100 Steps)</th>
<th>Speed Recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Relative SD (%)</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>101.7</td>
<td>0.6</td>
</tr>
<tr>
<td>iStepsP Lite</td>
<td>Low</td>
<td>69.7</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>100.3</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>158.3</td>
<td>10.5</td>
</tr>
<tr>
<td>Pedometer Lite</td>
<td>Low</td>
<td>8.7</td>
<td>35.3</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>70.3</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>125</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Self</td>
<td>89.7</td>
<td>3.2</td>
</tr>
<tr>
<td>LyrFree</td>
<td>Low</td>
<td>77.3</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>83.3</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>90.3</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Table 4: Summary of data from trials following 1km jog

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>Sensitivity</th>
<th>Actual Speed</th>
<th>Speed Detected</th>
<th>pc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trial 1</td>
<td>Trial 2</td>
<td>Trial 3</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>11.2</td>
<td>10.6</td>
<td>11.3</td>
</tr>
<tr>
<td>iStepsP Lite</td>
<td>Medium</td>
<td>11.0</td>
<td>11.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Pedometer Lite</td>
<td>Medium</td>
<td>11.3</td>
<td>11.2</td>
<td>11.8</td>
</tr>
<tr>
<td>LyrFree</td>
<td>Medium</td>
<td>11.6</td>
<td>11.3</td>
<td>11.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>Sensitivity</th>
<th>Steps Recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>iStepsP Lite</td>
<td>Low</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>52</td>
</tr>
<tr>
<td>Pedometer Lite</td>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>87</td>
</tr>
<tr>
<td>LyrFree</td>
<td>Low</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 5: Steps recorded in 1km car trip

At low speed (3 km/h), both the control pedometer and pedometer applications were inaccurate in recording speed and number of steps taken. (Table 1)
With regard to speed calculation over the 1km jog, the pedometer applications speed estimate generally correlated poorly with the actual speed calculated using an electronic stopwatch. (Table 4) Only the LYRFree application had a moderate correlation with actual speed, with a concordance correlation coefficient of 0.90.

Finally, the amount of background false steps recorded during a 1km car journey is shown in Table 5. This was found to be generally high in the pedometer applications at high sensitivity settings, whilst it was low in the case of the control pedometer.

**Discussion**

As has been observed in previous studies,(8,9) the accuracy of the pedometer applications and the control pedometer device is affected by activity intensity. Low intensity activity showed a higher relative standard deviation in the number of steps recorded and estimated speed, compared to moderate or high activity. Results for low intensity activity for all programs, as well as the control pedometer showed poor reliability and validity. The option of increasing sensitivity settings on the programs tested did allow PedometerLite to record an accurate step count (4.1% relative SD) and LyrFree to record an accurate speed (6% relative SD), but these sensitivity settings were not reliable and valid for all activity intensity levels. At moderate and high intensity activity, the control pedometer showed an acceptable relative standard deviation. iStepsLite on a medium sensitivity also showed reliability and validity for moderate and high intensity activity and was comparable to the control. All other programs were not as accurate as the control pedometer, and results showed varying degrees of reliability and validity, which also highlighting the need to choose an accurate program and calibrate for the intensity level undertaken.

When estimating speed, all programs and the control used a preset stride length multiplied by step count to determine the distance covered in a recorded time. The compounding effect of inaccuracy in estimating step count and discrepancy between actual stride length and a fixed stride length was seen in a higher relative standard deviation for estimate of speed than in step count, and shows a weakness in all programs and pedometers relying on this method of determining speed.

When considering estimation of distance in a pre-set 1km run, LYRFREE was found to be the most accurate of all the applications. It was also more accurate than the control pedometer with a concordance correlation coefficient of 0.9 compared to 0.1. This program operated with full GPS distance measurement in preference to step count. PedometerLite also had GPS functionality but did not show an improvement in distance and speed calculation, and did not appear to use the GPS preferentially when determine distance covered. While the control pedometer did have reasonable distance calculation and speed estimate, once again the inaccuracy in determining speed or distance using a preset stride length and recorded step count was apparent.

Car travel led to false recording of additional steps for all phone applications as well as the control pedometer. As expected more false steps were recorded with the higher sensitivity settings.

An accurate step count can be achieved with a free downloadable application by careful selection of program and manipulation of sensitivity settings, but this adds a level of difficulty and therefore a barrier to use of these programs as a simple clinical tool. When considering that the goal of the physician is to track physical activity, distance calculation and speed is far more beneficial to the clinician than step count. The use of GPS by LYRFree shows clear advantages over the control pedometer to determine the most accurate speed and distance. Furthermore the ability to upload and monitor progress, create or download routes, and set up a training program, are all additional benefits of this technology.

In our study one control pedometer was tested. There are likely varying degrees of accuracy over the range of pedometers available, some may be more accurate than the control pedometer tested. Given most pedometers have a similar mechanism of detecting steps and recording distance covered through fixed calculation of stride length, they could be predicted to display similar inaccuracies to our control pedometer without GPS support. Further limitations included using only free pedometer programs, while paid programs may be more accurate or more functional. Our aim was to determine if programs that were free for patients could be as effective as a bought pedometer, for those who did not want to purchase a device. A final limitation from our paper is that the programs were required to be turned on and run in the foreground to record steps. This requires patients to activate the programs at the beginning of an exercise period. An advantage of this is prevention of false recording of steps during other daily activities such as driving. As the exercise of most interest is moderate to high intensity, as opposed to activity throughout the day, if the patient was compliant with activation of the device, this would not
decrease the pedometers usefulness as a tool to record exercise periods.

**Conclusion**

Accuracy and utility of the downloadable programs lags behind the use of a commercially available pedometer when determining step count. It is possible to manipulate settings to improve step count accuracy at one activity level, but recalibration is required as intensity of activity changes. A weakness in both commercially available pedometers and pedometer applications is the inaccurate determination of speed and distance when a preset stride length is required for estimation of speed and distance. Use of GPS can overcome this problem and provided the most accurate results from our testing. Despite their limitations, the potential exists for pedometer applications to be a useful clinical tool in the primary care setting.

**Disclaimer**

Please check plan options with your carrier before using these programs, as downloading applications, connecting to the internet or using GPS support may not be covered by your plan.

**References**


ACCURACY OF USING A TABLET DEVICE FOR THE
USE OF DIGITAL RADIOLOGY MANIPULATION AND
MEASUREMENTS

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Background: Integration of information technology and the birth of e-health has been a phenomenon in the last few decades and currently it is thoroughly embraced. It has been a tampered concept in the past to use portable devices to access digital radiology. However necessary resolution and processing capabilities have not been available to meet the demands. With the integration of high-resolution tablet devices and easy access touch software, we are now at a point where this concept can finally become a reality. As part of this feasibility analysis we have conducted a small experiment to assess tablet devices and its ability to manipulate and gain measurements of complex high-resolution computed tomography (CT) images.

Methods: A human skeleton foot was put through an advanced 320 slice dynamic CT scanner. The obtained DICOM data was manipulated and distance measurements were taken using Osirix software between 2 very distinguishable points. The same 2 points were identified on the skeleton and the distances were measured precisely using calipers.

Results: When measuring distances using defined anatomical landmarks on a real skeleton and the CT scan on the iPad, the measurements correlated to within 1mm, with a mean percentage error of 1.3%. The tablet device image processing capability was very user friendly and ergonomic. However the software processing capability of the tablet was limited to simple distance measurements. The processing speed was inferior to a laptop and 3D reconstructions were not possible with the current software.

Conclusion: Tablet devices have reached the complexity needed to be an excellent portable digital radiology access point. However at the moment this remains as a concept envisioned but not applied. This concept currently is limited by the processing capability and the software design of these devices. This is undoubtedly going to change with the further advancement of tablet technology and its software.

Introduction
Apple Corporation® has just released the latest iPad featuring a high resolution “Retina Display” and it is a familiar feeling of yet another advancement to a device that has become a part of every day life. Tablet devices seem to be discovering their own niche in our society in the last 2 years. It is a familiar occurrence to the current generation of medical practitioners to have a tablet and smart phone devices using 3G/4G/Wi-Fi communication streams to efficiently and effectively communicate and acquire new information. The appeal of tablet devices has emerged through their portability and versatility compared to lap top computers.

The need for physicians and surgeons to understand the importance of information technology and the evolution of e-Health into the 21st century has been
well documented and the benefits have been well recognized. With its natural evolution into the 21st century the influence it had on Diagnostic Imaging was even stronger. The standardization of digital images acquired by the different medical imaging equipment has further facilitated the diffusion, transmission and communication in radiology within hospitals as well as on web. Since then all hospitals have seen the benefit of ‘filmless’ radiology and gradually have migrated to adopting this concept.

Tablet devices have been an extension of the concept of smart phones, which have mainly come about with the introduction of the iPad in April 2010. Even though initially seen as an ‘expensive toy’ more and more clinicians have taken to discovering ways for smartphones and tablet devices to be useful and have assimilated them into their practice. A growing number of ‘Apps’ are being used, including journals and textbooks, and surgical device instructions. Inevitability, the evolution of this technology is poised to be introduced into accessing radiology with the same portability and versatility. With such potential we can conceptualize radiological image manipulation and measurements by the clinician on the move, actively sharing image data with patients at bedside, effectively teaching students in radiology and advanced on the field research. Currently mobile Picture Archiving and Communication System (PACS) software are starting to emerge for smart phones and tablet devices, which are marketed heavily and is pushed by the tablet device enthusiasts. Advanced image manipulation software companies are also starting to focus on tablet and smart phone platforms.

It is true that a lot of current medical practitioners have mobile tablet devices. However when assessing feasibility and necessity of such a devices to aid our work, it is important to approach the situation with objectivity. The need for evidenced based practice with mobile technology is starting to be recognized as a necessity. As a first step in determining whether a tablet device has an integral role to play in the field of digital radiology processing, we conducted a small study to analyse and process 3D computed tomography (CT) rendered data using a tablet device. We attempted to manipulate the images and take accurate measurements using currently available tablet software. We hypothesise that novel iPad based software is an accurate interface for the measurement of anatomical data.

**Methods**

Using a Toshiba Aquillion One™ 320 slice CT scanner, we scanned a true skeleton foot and ankle model. Raw Digital Imaging and Communications in Medicine (DICOM) scan data and the 3D reconstructed DICOM data was sent through to an iPad 2 running Osirix app (Figure 1). The Osirix app is available on the Apple App store, costing $AUD31.99 and is a 24.7MB download. Osirix is a well calibrated software that has had wide utility in digital radiology processing in the past. We picked Osirix as it was apparent through database searching that it was the most user friendly/advanced radiology software available for this platform even at this time. Using the foot and ankle models, the same bony landmarks were identified on the physical model, and the pre-prepared, 3D reconstructed data on the iPad. These distances were then measured using calipers, and using the Osirix app on the iPad (Fig 2-4).

Subsequently, measurements from a real CT scan of a wrist, and head, were then performed using prominent anatomic landmarks. The gold standard was considered to be measurements taken using the calibrated Aquillion one CT scanner and its inbuilt Vitrea software. Measurements were then taken on the iPad and compared to the gold standard.

After scanning the foot, raw DICOM data as well as 3D rendered data was sent through to the iPad using a Digital Video Disc (DVD) and linking through iTunes. Even though PACS network linking capabilities existed with Osirix software, the Southern Health PACS server did not accommodate such access at the time.

With the current software capabilities of iPad version of Osirix, simple viewing, distance measurements and area measurements were only possible. 3D reconstructions were not possible with the app version unlike its laptop/pc counterparts. Since 3D reconstructions were not possible we could only use Osirix to apply distance markers on 2 dimensional planes. Thus to get accurate 3D distances the correct orthogonal plane rotation of the scan was needed and distance markers added with easy finger drags (Figure 5).

Technical aspects and difficulties of this process were carefully recorded.

**Results**

**Quantitative Analysis**

There was very clear identification of bony landmarks by Osirix software (Figure 1). Applying the distance markers was a simple finger dragging process with surprising accuracy and ease. The results correlated to within 1 millimeter (mm) of the measured results from the iPad and the actual caliper results from the
skeleton (Table 1). The average percentage for error for these measurements was 1.3%.

When comparing the 3d marker measurements to the iPad measurements (done using 2D reconstructions in the appropriate plane), we found that there was a mean discrepancy of 2.6%. The CT head measurements were accurate to within 0.1mm (Table 2).
Measurements were easily possible using the finger drag to position the ruler. The process was very accurate and much simpler than the precision required to position such markers with a mouse. Repositioning the markers were just as simple by re dragging the markers to the desired points.

Very easy portable image correction with regards to colour/hue/saturation was possible using an iPad 2 device with a simple touch screen finger drag. Browsing between slides was much simplified yet again with simple finger drag techniques.

With regards to the difficulties of this process it was clear that compared to an average desktop computer/laptop, the processing speed of the iPad 2 still seemed inferior. Rapid browsing between image series still appears to be limited by lagging image data compared to its pc counterpart versions. When handling 3D volume rendered image browsing iPad version required about 1 second to load each slide.

Also the software available for iPad 2 for radiology image processing still appears to be of a simple design at the moment. Apart from distance/angle measurements, no other image processing was possible (Figure 1).

Table 1: Measurements taken using iPad and acaliper measure of markers on foot and ankle model. All measurements in millimeters.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Caliper Measur</th>
<th>iPad measurement</th>
<th>Percentage error of iPad measurement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker 1 (Fig 2)</td>
<td>44</td>
<td>44.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Marker 2 (Fig 3)</td>
<td>59</td>
<td>59.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Marker 3 (Fig 4)</td>
<td>23.5</td>
<td>23.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 2: Measurements taken to perform dynamic volume rendering of a wrist and head. All measurements in millimeters.

<table>
<thead>
<tr>
<th>Dynamic Volume Rendered Wrist</th>
<th>3D marker measurement from scanner</th>
<th>iPad measurement</th>
<th>Percentage error of iPad measurement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd metacarpal</td>
<td>48</td>
<td>45.2</td>
<td>5.8</td>
</tr>
<tr>
<td>3rd Metacarpal</td>
<td>41.3</td>
<td>41.2</td>
<td>0.2</td>
</tr>
<tr>
<td>4th metacarpal</td>
<td>48.1</td>
<td>46</td>
<td>4.4</td>
</tr>
<tr>
<td>5th metacarpal</td>
<td>47.1</td>
<td>46.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Radial styloid to trapzium</td>
<td>24.8</td>
<td>23.3</td>
<td>6.1</td>
</tr>
</tbody>
</table>

| CT head                       |                                   |                  |                                         |
| Sagittal diameter             | 155.3                             | 155.3            | 0.0                                     |
| Coronal Diameter              | 131.3                             | 131.3            | 0.0                                     |

| 2D CT distal radius           |                                   |                  |                                         |
| Ulna styloid to Radial Styloid| 43.4                              | 42.3             | 2.5                                     |
| Diameter of the capitate      | 22.5                              | 23.1             | 2.7                                     |

Discussion

The idea of a portable device to access digital radiology is not a novel concept. It was tampered in the early part of 2004 with the use of PDA (personal digital assistant) in Beth Israel Deaconess Medical Centre, Boston United States. In this institute digital radiology reporting and transmission was done using small PDAs and they predicted their techniques will be common practice in two to three years. They saw the potential in a versatile and a portable radiology device and envisioned it as an excellent radiology teaching tool. However it was clear that even though this was a great concept, the demands of digital radiology exceeded the technological capability at that time. Even though they justified many uses for their practice, it could be argued that similar functions would still been possible from a portable laptop device.

The human eye is limited by our retinal rods and cones have a maximal resolution capability of 2 lines per minute arc (able to distinguish 2 lines spaced at 1/60 of a degree).\(^9\) The recently released iPad“3” boasts specifications of 2048 x 1538 square pixel resolution on a 24.2cm x 18.5mm with the 24 bit colour display which is on par with the best desktop digital radiology processing computers.\(^10\) Therefore by mathematics we can approximate that if an iPad“3” is held at 50cm from our eyes our maximal perceived resolution at that angle would be 1236 lines. (Fig 6) Therefore one can argue that with the new iPad“3” specifications of 1538 pixels on a short axis, we have exceeded the maximal resolution of the eye providing its held at arms length (50cm).
Perceived angle = \tan^{-1}(\frac{18.5}{2}) / 50 = 10.48

Maximal perceived resolution = 10.48 x 10.48 x (2 x 60) = 1236

Figure 6. Perceived angle of resolution of new generation iPad.

Through this simple demonstration study, we have managed to show that an iPad can be used to handle CT image data. It was clear that the current software available yielded very accurate measurable results. Currently the main limitation lies within the processor capability and software features. These at the moment limit functions that medical practitioners would expect from a portable radiology device. It was clear that complex reconstructions and 3D rendering processes is still not possible using an iPad alone. This limits getting accurate 3D measurements and manipulations, which is becoming more and more of a necessity for medical specialties such as orthopaedic and neurosurgery. However it was just as possible to quickly and accurately measure pre rendered 3D data with desired clinical accuracy using an iPad. From the aspects of ergonomics, user friendliness and portability the iPad appeared to be far superior compared to a laptop computer.

In conclusion it was clear that in comparing information processing capability the iPad 2 as a tablet device was inferior to laptop and desktop computers. Its radiology handling at the moment is of a simple design focused on simple viewing. However the key to a tablets contribution lies in its portability and versatility. Conceptually it is a great portable reference tool for simple radiology access at any situation such as ward rounds, teaching and outpatient setting. It can be argued that there would be an increase in productivity using these devices. Quantifying this is currently conceptually difficult. At the moment processing and software capabilities appear to be the limiting factor for advocating wide spread use of tablets for digital radiology. Even with current software its potential as an excellent radiology reference device is evident. With the natural assimilation of tablet technology to the practice of doctors further rapid enhancement of radiology software and processing capability is needed. With the capabilities and specifications of the new released iPad with a high resolution display, these limitations may already have been addressed. If current trends continue tablet devices will become a very strong platform to handle digital radiology and its undoubted increase in productivity will reveal itself.

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Case Report

A 60 year old male presented to the emergency department of a rural hospital following a minor head injury with symptoms of confusion and headache for ten hours. Significant past medical history included atrial fibrillation (treated with warfarin), diabetes and hypertension. Initial clinical examination revealed a Glasgow Coma Scale (GCS) of 12 (eye opening to voice, localizing to pain, confused), and weakness was noted on the left side graded at 3/5. Lab testing revealed a normal platelet count and an elevated International Normalised Ratio (INR) of 3.2. An urgent Computerised Tomography (CT) brain (CTB) was performed and a right sided 1.7cm acute on chronic subdural haemorrhage (SDH) with 8mm of midline shift was seen. The hospital had no after-hours radiology service thus the images were sent to an off-site radiology reporting company.

After initiating reversal of warfarin, a referral was made to a neurosurgical unit. Due to the limited ability of the referring resident to interpret the scan and convey this information verbally, and the delay in waiting for off-site radiology to report the scan, the neurosurgical service requested a picture to be sent of the scan for review. Unfortunately the resident had chosen a slice of the CTB which showed minimal SDH which would not have accounted for the patient’s symptoms or signs. At this stage, the neurosurgical service requested a video MMS of the CT brain. This was done by video recording using a smartphone (Apple® iPhone 4) whilst scrolling through the slices of the CTB on the hospital computer. The registrar was then able to view the entire CT brain, which showed the large acute on chronic subdural haemorrhage with significant midline shift which warranted immediate neurosurgical intervention.

Urgent transfer was arranged to the receiving neurosurgical unit at the tertiary metropolitan hospital. A copy of the CTB was sent on CD with the patient and was reviewed to confirm the imaging findings. The patient underwent an emergency mini-craniotomy and evacuation of SDH. Post operatively the patient made gradual improvements in their neurological state and was transferred to a rehabilitation facility day six post operatively.

Discussion

Neurosurgery is a highly specialised field of medicine, restricted to major metropolitan tertiary hospitals. The potentially high acuity of intracranial pathology means that any delay of transfer to a neurosurgical unit may result in significant morbidity and mortality. Traditionally, referral of an emergency neurosurgical condition has relied on voice-only telephone conversation and therefore verbal reporting of
imaging findings. With advances in technology, recent years have seen referrals being supplemented by emailing of images, and more recently picture multimedia messaging system (MMS). Off-site access to image viewing software has also assisted in the referral process, however with different hospitals and networks utilising different imaging software and access requirements, this is currently of limited benefit. This case report outlines how the use of video MMS, as opposed to picture MMS can aid in referral to a neurosurgical unit, expediting transfer and definitive management.

The use of video MMS in this case assisted both the referring doctor, and the registrar receiving the referral. The resident, with no formal training interpreting a CT brain was able to share the entire CT without having to select which slice to share. This resulted in the on-call registrar being able to view all of the relevant slices to gain as much information as possible. This is particularly useful in a rural emergency setting, where often there is a sole junior doctor on duty overnight.

This technology relies on both the referrer and on-call registrar to have access to a phone with MMS capabilities. There is significant cost associated with the purchase of smart phones and sending of MMS messages, usually absorbed by the individual doctor. However, Manhattan Research demonstrated that 81% of physicians in the United States own a smart phone, making this technology accessible to most doctors.1

To ensure best technique, the camera should be placed approximately 20-30cm away from the screen, focused on the computer screen prior to the start of recording. Camera auto—exposure should be set to give the best view of brain parenchyma/bony windows as relevant. For example, on the iPhone 4s this can be done by clicking on ‘brain’ on the picture prior to starting to record. The images should then be scrolled though reasonably quickly to ensure all images in the sequence (eg axial) are seen. MMS in Australia are limited to 500kb (approximately 30seconds). If two sequences are being sent, they should be sent as separate files to reduce the chance of message send failure. Ideally, images are viewed by pausing the video MMS sequence and then scrolling backwards and forwards manually by the recipient (eg on iPhone “scrubbing”). There is also potential for sending the captured video as an email message directly from the smart phone.

Various studies have previously investigated the use of picture and video MMS for the purposes of image transfer, with most studies showing promising results.2,5 Furthermore, the neurosurgical use of video transfer of images has previously been validated in a study by Waran et al6 where they found that from 56 prospectively collected video MMS’s interpreted by two separate neurosurgeons, they agreed on the diagnosis in every case, with only one case where the neurosurgeon’s interpretation of the scan differed from the radiology report, resulting in a kappa value of 0.88.

A potential pitfall is that some smartphone cameras are fitted with only a low quality video recorder, and as such it may not be adequate in certain instances. Furthermore, the images transmitted may not be adequate to diagnose subtle lesions. However it must be noted that in most neurosurgical cases, if a lesion is too subtle to be seen, it is unlikely to represent a patient requiring urgent neurosurgical intervention. Also, it is noted that video MMS’s sent via Apple’s iMessage© system are of higher quality when compared to regular MMS. This is likely to be related to higher data transfer capacity over the iMessage network. In instances where the quality is too low to interpret, the recipient must be aware of this and request alternate methods of image transfer.

Maintaining confidentiality of both patient and doctors with MMS messaging also requires consideration. With smartphones requiring internet connection for MMS services, this offers the potential for phone security issues, and also for accessing images should the phone fall into the wrong hands. Ensuring smartphones are secured with a passcode (at both sending and receiving ends) can help minimize this. Where possible, it is advisable to obtain consent from patient’s when transmitting their imaging to a third party, though in the emergency setting this may not be feasible.

Sharing images with this technique also requires doctors to share their personal phone numbers with one another. Whilst this can be minimised by having a smartphone dedicated to the receiving unit, one is not always provided. Conversely, by having direct contact details of the referring and receiving doctor, this does facilitate easier communication between the two parties.

Inadequately labelled video MMS messages are a potential for medical errors. If multiple referrals are received to the same smartphone, there is potential for confusion of images between patients. The video resolution is not typically high enough to read patient demographics displayed on the individual scans. There are various strategies to deal with this, such as to request the name/DOB of the patient to be sent with the image, or request that the sending doctor ensure
they focus on the name/date of birth of the image at the start of the recording before scrolling through the rest of the images.

In conclusion, Video MMS can be a very useful modality for image sharing between hospital networks, when remote/offsite access is not available. It can be particularly useful for expediting the referral and transfer of acute neurosurgical patients from peripheral hospitals, where there is often only junior medical staff and no onsite radiology service after hours. However, care should be taken when using such technology to ensure confidentiality and security of images, picture quality and accuracy of patient labelling is maintained.

References


