

component of clinical competence. As most medical schools use objective structured clinical examinations to assess performance during training,<sup>9</sup> earlier remediation of suboptimal level of performance could ultimately improve the quality of asthma management in practice. Because these skills sets are required to manage other chronic conditions,<sup>10</sup> the establishment of minimum performance benchmarks during training could have an overall positive effect on the quality of chronic disease management.

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1. Johnson AJ, Nunn AJ, Somner AR, Stableforth DE, Stewart CJ. Circumstances of death from asthma. *Br Med J (Clin Res Ed)*. 1984;288(6434):1870-1872.
2. Wu AW, Young Y, Skinner EA, et al. Quality of care and outcomes of adults with asthma treated by specialists and generalists in managed care. *Arch Intern Med*. 2001;161(21):2554-2560.
3. Reznick RK, Blackmore D, Dauphinee WD, Rothman AI, Smees S. Large-scale high-stakes testing with an OSCE: report from the Medical Council of Canada. *Acad Med*. 1996;71(1)(suppl):S19-S21.
4. Papadakis MA. The Step 2 clinical-skills examination. *N Engl J Med*. 2004;350(17):1703-1705.
5. Régie de l'assurance maladie du Québec. *Prescription Drug Insurance*. Québec, Canada: Régie de l'assurance maladie du Québec; 2004.
6. Becker A, Bérubé D, Chad Z, et al. Canadian Network For Asthma Care; Canadian Thoracic Society. Canadian Pediatric Asthma Consensus guidelines, 2003 (updated to December 2004): introduction. *CMAJ*. 2005;173(6)(suppl):S12-S14.
7. Tamblyn R, Abrahamowicz M, Dauphinee WD, et al. Association between licensure examination scores and practice in primary care. *JAMA*. 2002;288(23):3019-3026.
8. Tamblyn R, Abrahamowicz M, Dauphinee D, et al. Influence of physicians' management and communication ability on patients' persistence with anti-hypertensive medication. *Arch Intern Med*. 2010;170(12):1064-1072.
9. Petrusa ER, Blackwell TA, Ainsworth MA. Reliability and validity of an objective structured clinical examination for assessing the clinical performance of residents. *Arch Intern Med*. 1990;150(3):573-577.
10. Wagner EH, Bennett SM, Austin BT, Greene SM, Schaefer JK, Vonkorff M. Finding common ground: patient-centeredness and evidence-based chronic illness care. *J Altern Complement Med*. 2005;11(suppl 1):S7-S15.

## Smartphones in Clinical Practice, Medical Education, and Research

Cellular phone technology and additional hardware were integrated into personal digital assistants<sup>1</sup> and they evolved into smartphones. The installation of high-speed cellular networks with near-universal coverage has allowed these devices to show their full potential, which also benefits users in the medical community. Long-term Evolution technology (LTE), the high end of the fourth generation (4G) of mobile networks, offers speeds up to a hundred times faster than 3G. Currently, 64% of US physicians own smartphones, but this is predicted to increase to 81% penetration by 2012.<sup>2</sup>

**Anatomy and Physiology of Smartphones. Hardware.** Today's high-end smartphones feature capacitive (finger gesture enabled) or noncapacitive (stylus enabled) high-resolution touch screens, discrete or screen keypads, communication ports such as mini-USB, infrared, Bluetooth, wireless local area network radios, assisted global positioning technology, electronic compasses, accelerometers, gyroscopes, proximity and ambient light sensors, microphones and cameras for videoconferencing, and inductive, cable-free battery charge technology.

**Software.** The most critical aspect of any computer is the software it is running, since it ultimately determines usability, usefulness, and user adoption (see eTables 1 and 2 and eFigures 1-3; <http://www.archinternmed.com>). Other important aspects include multitasking, adherence to industry standards, and availability of native software applications (**Figure** and eFigure 2) vs simple mobile Web pages (Web apps) (Figure and eTable 1).

**Smartphone Applications. Clinical Practice.** Most health care professionals desire current clinical information and decision support at the point of care. Smartphones can provide both by accessing traditional medical textbooks, professional society guidelines, drug references, and institution-specific therapy standards. Medical calculators simplify the bedside use of medical equations, scores, stratification, and risk prediction and prevention models. Smartphones can assist with physical examinations using applications to check hearing, eyesight, and color recognition; evaluate mental status; or photograph or video document physical findings.

Taking full advantage of current technology means wireless retrieving of the most up-to-date information anywhere anytime. The National Library of Medicine's "PubMed for handhelds" engine and third-party applications offer searches structured by diseases and conditions, medical specialties, differential diagnosis, drugs and medications, and journals and medical news or use a latent semantic analysis framework.

Our patients expect information about their conditions, the treatments, and procedures we offer them. Illustrations and videos formatted for mobile display can

Operating system (OS)	Android OS	Blackberry OS	iPhone OS	Maemo OS	Symbian OS	Palm Web OS	Windows Phone
Owner	Open Handset Alliance (OHA)	Research In Motion	Apple	Nokia	Nokia	Hewlett Packard	Microsoft
Open source	Yes	No	No	Yes	No	Yes	No
Owner Web site	<a href="http://www.android.com">http://www.android.com</a>	<a href="http://www.rim.com">http://www.rim.com</a>	<a href="http://www.iphone.com">http://www.iphone.com</a>	<a href="http://www.maemo.org">http://www.maemo.org</a>	<a href="http://www.symbian.org">http://www.symbian.org</a>	<a href="http://www.hpwebos.com">http://www.hpwebos.com</a>	<a href="http://www.windowsphone.com">http://www.windowsphone.com</a>
Multitasking	Yes	No	Yes	Yes	Yes	Yes	Yes
Current version	3.1	6	4.3	5	9.4	3	6.5
<b>Software included with operating system</b>							
Included file manager	No	No	No	Yes	Yes	No	Yes
Office document reader	No	Doc, pdf, ppt, xls	Doc, pdf, ppt, xls	NA	Doc, pdf, ppt, xls	Doc, pdf, xls	Doc, pdf, ppt, xls
Flash/Java script support	No/yes	No/yes	No/yes	Yes/yes	No/yes	Yes/yes	Yes/yes
Java Interpreter (J2ME)	No	No	No	Yes	Yes	No	No
Software repository	<a href="https://market.android.com">https://market.android.com</a>	<a href="http://blackberry.com/appworld/">http://blackberry.com/appworld/</a>	<a href="http://www.itunes.com">http://www.itunes.com</a>	<a href="http://www.maemo.org/downloads/">http://www.maemo.org/downloads/</a>	<a href="http://store.ovi.com/">http://store.ovi.com/</a>	<a href="http://www.palm.com/appstore/">http://www.palm.com/appstore/</a>	<a href="http://marketplace.windowsphone.com">http://marketplace.windowsphone.com</a>
Supported E-mail protocols	IMAP4, POP3	Proprietary	IMAP4, POP3	IMAP4, POP3	IMAP4, POP3	IMAP4, POP3	IMAP4, POP3
Push mail support	Gmail	Proprietary	Exchange Active Sync	Exchange Active Sync	Proprietary	Exchange Active Sync, Gmail	Exchange Active Sync
Instant messaging	Google Talk	Windows Live, Blackberry PIN	No	Yes	No	Google Talk AOL IM	Windows Live
Web browser (standard)	Chrome Lite (Webkit)	Blackberry Browser	Safari (Webkit)	Maemo (Gecko)	Nokia (Webkit)	Web OS Browser (Webkit)	IE Mobile
<b>Backup and Synchronization</b>							
Desktop software	No	Device manager, Media sync	iTunes	NA	Nokia PC Suite	iTunes	Active Sync, Device Manager
Desktop Sync (mail, contacts, calendar, media)	No	Yes/yes/yes/music only	No/yes/yes/yes	NA	Yes/yes/yes/yes	No	Yes/yes/yes/yes
Internet Sync (mail, contacts, calendar, media)	Yes/yes/yes/yes	Yes/yes/yes/no	Yes/yes/yes/no	NA	Yes/yes/yes/yes	No/yes/yes/no	Yes/yes/yes/yes
Internet Sync and Services	Gmail and Google	RIM Proprietary	Exchange, Mobile Me	NA	Exchange, Ovi	Synergy	Exchange, My Phone
<b>Software development</b>							
<b>Developer Web site</b>	<a href="http://developer.android.com">http://developer.android.com</a>	<a href="http://developer.blackberry.com">http://developer.blackberry.com</a>	<a href="http://developer.apple.com/iphone">http://developer.apple.com/iphone</a>	<a href="http://maemo.org/development">http://maemo.org/development</a>	<a href="http://developer.symbian.org">http://developer.symbian.org</a>	<a href="http://developer.palm.com">http://developer.palm.com</a>	<a href="http://create.msdn.com/en-US/">http://create.msdn.com/en-US/</a>
Software development kit	Android SDK/NDK	Blackberry JDE	iPhone SDK	Maemo SDK	Carbide C++	Mojo SDK	Visual Studio Professional
Support host operating systems	Windows, Mac, Linux	Windows	Windows, Mac	Linux	Windows	Windows, Mac, Linux	Windows
<b>Biomedical use</b>							
Availability of medical and scientific software	***	**	****	*	*	****	*
<b>Medical software applications (direct link)</b>	<a href="http://ht.ly/1V8e1">http://ht.ly/1V8e1</a>	<a href="http://ht.ly/1V7Y2?">http://ht.ly/1V7Y2?</a>	<a href="http://ht.ly/1V8ff">http://ht.ly/1V8ff</a>	NA	<a href="http://ht.ly/1V8jx">http://ht.ly/1V8jx</a>	<a href="http://ht.ly/1V8mr">http://ht.ly/1V8mr</a>	<a href="http://ht.ly/1V8nF">http://ht.ly/1V8nF</a>
QR code							
<b>Scientific software applications (direct link)</b>	<a href="http://ht.ly/1V7W6">http://ht.ly/1V7W6</a>	<a href="http://ht.ly/1V80u">http://ht.ly/1V80u</a>	<a href="http://ht.ly/1V8gw">http://ht.ly/1V8gw</a>	<a href="http://ht.ly/1V8i7">http://ht.ly/1V8i7</a>	<a href="http://ht.ly/1V8i0">http://ht.ly/1V8i0</a>	<a href="http://ht.ly/1V8mr">http://ht.ly/1V8mr</a>	<a href="http://ht.ly/1V8oK">http://ht.ly/1V8oK</a>
QR code							

**Figure.** Comparison of smartphone operating systems (platforms). To quickly access the Web links from a smartphone, QR codes (quick response matrix [2D] barcodes) were included. Please install one of the free barcode readers, ie, i-nigma (<http://ht.ly/1Vkt8>), available for virtually all smartphones, and scan the QR code with the built-in camera and it will direct you to the Web page. In the row "Availability of medical and scientific software," the asterisks represent the scale of availability (\*least available; \*\*\*\*, most available). NA indicates not available.

assist obtaining informed consent at the office or bedside.

Health care is affected by globalization and migration of people, resulting in the need to interact with them (and their relatives) in languages we may not speak or understand. Text-to-speech, speech-to-text, and speech-to-speech translation have become a reality. They could be particularly useful for deployment in disaster relief teams.

Smartphone solutions to fully access and edit electronic medical records including coding and billing have been deployed. They are no longer restricted to numeric or text data and allow viewing of "digital information and communication in medicine" (DICOM) formatted 3-dimensional imaging data from "radiology information" or "picture archiving and communication systems" (RIS/PACS) in conventional radiology, ultrasonography, computed tomography and magnetic resonance imaging, or endoscopy. Sensors for both, radio-frequency device identification devices (RFID)—best known from electronic passports—and biometric data (user's skin [fingerprint, handprint, palm print, knuckle print, blood vessel pattern], eye movement and face recognition, ear canal sensory, individual voice pitch recognition, odor, and DNA detection) are being considered for

smartphone integration.<sup>3,4</sup> RFIDs can also be injected<sup>5</sup> or implanted (skin or molar teeth) to allow emergency responders identify and assist victims faster.

Smartphones can also be used to monitor patients outside the medical enterprise. Wearable real-time cardiovascular disease detectors are already available<sup>6</sup> and electrocardiographic and arrhythmia monitoring may soon be fully integrated into smartphones.<sup>7</sup>

**Education.** Software repositories are replete with multimedia rich educational applications covering virtually every biomedical subject. Board-certified health care providers who periodically need to revalidate their credentials can now earn Continuing Medical Education (CME) credits on the go. Smartphones can serve highly customized educational and scientific content through RSS feeds, podcasts (eTable 2 and eFigure 3), social media (eFigure 1), and other Web 2.0 technologies (CMS [content management system], LMS [library management system], or VLE [virtual learning environment]) (eFigure 2).

**Research.** There are applications to emulate scientific graphing calculators; render chemical compounds and proteins in 3 dimensions; help prepare standard laboratory solutions; view restriction enzyme information, tu-

torials, and protocols; and watch laboratory video tutorials (Figure and eFigure 2).

Smartphone-attached “laboratory on chip” (LOC) devices with modular microfluidic chips based on optoelectrowetting technology can perform sample preparation and detection steps in a simple and automated manner; LOC devices to run capillary electrophoresis, real-time polymerase chain reaction, flow cytometry, enzymatic assays, biomarker screening, and immunoassays have been developed.<sup>8,9</sup>

**Outlook.** Real-time medical and scientific communication and information is already at our fingertips, literally. A breakthrough will be “biocommunicators” incorporating a whole new dimension of information. Feasible potential applications include population-based cancer screening; prediction of drug response for biological or targeted therapies using genetic polymorphisms; environmental monitoring; on-site and bedside detection of critical laboratory and drug values on house calls by emergency responders; as well as clinical research with home-based collection of real-life biomedical data and FDA (Food and Drug Administration)-demanded patient-reported outcomes.

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**Online-Only Material:** eTables 1 and 2 and eFigures 1, 2, and 3 are available at <http://www.archinternmed.com>; they provide categorized exemplary software applications and other Internet-based resources for the various use scenarios in clinical practice, research, and biomedical education discussed. They include a brief marketing description (drawn from the app vendor’s site) and clickable hyperlinks for easy access. No endorsement is made or implied. Trademarks, logos, and ad copy are the property of the respective owners.

1. Baumgart DC. Personal digital assistants in health care: experienced clinicians in the palm of your hand? *Lancet*. 2005;366(9492):1210-1222.
2. Manhattan Research. Physician smartphone adoption rate to reach 81% in 2012. Accessed March 19, 2011.
3. Rosenblatt MN, Hotelling SP. Touch Screen RFID Reader Tag. Accessed March 19, 2011.
4. Fadell A, Hodge A, Schell S, et al. Embedded authentication systems in an electronic device. <http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&sp=1&u=%2Fnetacgi%2FPTO%2Fsrchnum.html&r=1&f=G&l=50&s1=%2220090083850%22.PGNR.&OS=DN/20090083850&RS=DN/20090083850>. Accessed March 19, 2011.
5. Troyk PR. Injectable electronic identification, monitoring, and stimulation systems. *Annu Rev Biomed Eng*. 1999;1:177-209.
6. Oresko JJ, Duschl H, Cheng AC. A wearable smartphone-based platform for real-time cardiovascular disease detection via electrocardiogram processing. *IEEE Trans Inf Technol Biomed*. 2010;14(3):734-740.
7. Lin G, Nakajima T, Rahul P, Hodge A. Seamlessly embedded heart rate monitor. Accessed March 19, 2011.
8. Li J; National Aeronautics and Space Agency Ames Research Center. NASA Ames Scientist Develops Cell Phone Chemical Sensor. <http://www.nasa.gov>

/centers/ames/news/features/2009/cell\_phone\_sensors.html. Accessed March 19, 2011.

9. Malic L, Brassard D, Veres T, Tabrizian M. Integration and detection of biochemical assays in digital microfluidic LOC devices. *Lab Chip*. 2010;10(4):418-431.

## Patients With Infectious Diseases, Overcrowding, and Health in Hospital Staff

The evidence on whether treating patients with infectious diseases increases the risk of ill health among hospital staff is limited to specific infectious agents, such as methicillin-resistant *Staphylococcus aureus* (MRSA).<sup>1-7</sup> However, any infectious agent that can be transmitted by airborne transmission or during treatment contact can be acquired at the workplace. We therefore examined whether the overall prevalence of infectious diseases among patients predicts ill health in hospital staff treating them, as indicated by increased absence from work because of sickness and antibiotic medication use. Furthermore, as patient overcrowding has been suggested to increase the transmission of infectious diseases within hospitals, we also studied whether there is an association between patient overcrowding and prevalence of infectious diseases and whether the association between the prevalence of patients with infectious diseases and ill health in hospital staff is dependent on ward overcrowding.

**Methods.** Study participants comprised 993 physicians and nurses (mean age, 42.4 years; 93.7% female; 84.7% registered nurses) in 54 somatic disease hospital wards in 5 acute care hospitals in Finland. The assessment methods used have been described previously.<sup>8,9</sup> Briefly, ward-level prevalence of infectious diseases (hospital and community acquired) and other patient characteristics were assessed from case records of the 1102 patients in these wards.<sup>8</sup> Ward overcrowding was determined using routinely collected monthly figures on bed occupancy for each ward.<sup>9</sup> These ward-level data were linked to individual records on the employee sickness absence and antibiotic medication use (purchases of medicine with the World Health Organization Anatomical Therapeutic Chemical Classification code J01) during the subsequent 150 days. The records were obtained from employers’ and nationwide health registers.<sup>9</sup>

Binary logistic regression analysis with the SAS multilevel GLIMMIX procedure was used to study the associations of ward-level exposure to infectious diseases with individual-level employee sickness absence (yes/no) and recorded antibiotic use (yes/no). The models were adjusted for employee characteristics (sex, age, occupation, type of employment, and chronic disease) and ward-level characteristics (ward specialty, mean age of patients, number of patients, mean number of invasive devices in patients, prevalence of operated patients, and patient overcrowding). To examine whether the associations were dependent on the level of patient overcrowding at the ward, the interaction term “overcrowding × exposure to infectious diseases” was entered into the model after entering the main effects of overcrowding and exposure to infectious diseases.