Caveats of smartphone applications for the cardiothoracic trainee

Joy C. E. Edlin, MRCS, and Ranjit P. Deshpande, FRCS

Background: The clinical environment is becoming increasingly dominated by information technology, most recently the smartphone with its applications (apps) of a multitude of uses. There are already tens of thousands of medical apps available for download, to educate both patients and trainees, and many more are being designed to facilitate delivery of care. The rapid development of this technology has outgrown its quality evaluation and regulation, both urgently required to maintain patient safety, protect sensitive data, and ensure dissemination of accurate information. We review medical apps themed towards cardiothoracic surgery in terms of medical professional involvement in their content and design.

Methods: iTunes and Play Store were searched for cardiothoracic surgery-themed medical apps, using the terms *cardiothoracic*, *thoracic*, *cardiac*, *heart*, *lung*, *surgery*, and variations thereof and including the term *medical*.

Results: A focused search yielded 379 apps, of which 6% were associated with a named medical professional, 15% with a publisher or professional society, and 63% with a user rating.

Conclusions: The findings suggest inadequate input from the medical profession. The article discusses the pressing issues regarding quality evaluation, regulation, and information security, required for smartphones and handheld devices to become an integral and safe part of delivery of care. (*J Thorac Cardiovasc Surg* 2013;146:1321-6)

Information technology (IT) is playing an ever-larger role in our lives and is finding important applications within our careers and daily clinical routine as physicians and surgeons. We use our mobile telephones instead of bleeps and the Internet on our smartphones as a quick reference tool. Most Trusts in the United Kingdom have digitalized their imaging and laboratory services, patient records, and prescription charts, and some even offer portable computers for the medical teams on ward rounds. Radiologists can access the Picture Archive Communication System to view and report on images in the middle of the night without leaving home. Private health care providers already offer their consultants intrasite and smartphone access to their patients' up-to-date nursing notes, laboratory test results, and radiographic reports. With the current use of smartphones and their applications (apps), even more benefits to the delivery of patient care may be seen in the future. However, many caveats relating to the regulation and security of confidential patient data remain, and this article aims to shed light on these issues. We also attempt to critically evaluate apps available to cardiothoracic surgery trainees.

APPLYING SMARTPHONE TECHNOLOGY TO MEDICINE

Since May 2012, the National Health Service (NHS) "Hack Day" has become a regular melting pot of ideas for health care staff and software developers to design smartphone apps supporting the health care profession.¹ Projects have included developing an app to facilitate handover, looking to make paper obsolete.² In the United States, "iRound" is already in use by some physicians to facilitate handover and simplify job lists.³ Wales Deanery offers all its foundation year 1 trainees free access to numerous medical textbooks via smartphone apps.⁴ Evidently, information technology is becoming an integral part of medicine.

Smartphones combine multiple technologies, making their use more versatile than that of a simple mobile telephone. Each technology and their combined capabilities can be used in different apps for our daily or professional lives. They can also be connected to other devices, creating a cheap and portable tool. As such, smartphones have the potential to revolutionize and facilitate delivery of care in medicine in a cost-efficient manner.

Via Internet access, smartphones enable a wealth of knowledge to be available almost instantaneously. From the palm of their hand, clinicians could access information about medications, symptoms, diagnoses, and the patient's electronic health record and radiographic imaging results, without ever leaving the patient's side.⁵ This capability makes use of smartphones a powerful learning tool. Knowles described that adult learners have a task- or problem-centered approach to learning⁶ (ie, their learning is driven by the identification of a problem and the need to solve that problem). Physicians learn best when they

From the Department of Cardiothoracic Surgery, King's College Hospital, London, United Kingdom.

Disclosures: Authors have nothing to disclose with regard to commercial support. Received for publication Dec 10, 2012; revisions received March 10, 2013; accepted for publication Aug 10, 2013; available ahead of print Oct 7, 2013.

Address for reprints: Joy C. E. Edlin, MRCS, Department of Cardiothoracic Surgery, King's College Hospital, Denmark Hill, London SE5 9RS, United Kingdom (E-mail: joy.edlin@nhs.net).

0022-5223/\$36.00

Copyright © 2013 by The American Association for Thoracic Surgery

<http://dx.doi.org/10.1016/j.jtcvs.2013.08.033>

Abbreviations and Acronyms

app	= application
EU	= European Union
FDA	= Food and Drug Administration
IT	= information technology
NHS	= National Health Service

perceive that which they learn as relevant to their practice.⁷ Through their ability to deliver knowledge at the point of care, smartphone apps can, thus, enhance adult and clinical learning.

The Internet and Bluetooth technology could be used to send radiographic and ultrasonographic images, enabling rapid communication and advice from senior colleagues off-site, permitting early diagnosis and intervention, potentially improving patient outcome. The advancement of touchscreen technology allows smartphones to dedicate more of their “face area” to the screen, thus creating an ergonomic solution to handheld video devices.

The current processing power, combined with screen sizes of smartphones, enables videos and audio playback and the performance of complex calculations. These functions are used in many medical apps, including videos of procedures (“Campbells Operative Orthopaedics: Core Techniques”), playing heart and respiratory sounds for educational purposes (“Stethoscope Sounds”), solving the Cockcroft-Gault equation (“Renal Calc”), performing dosage calculations (“Paediatric Emergency Drugs”), or helping to interpret an electrocardiogram by measuring the PR interval (“Electrocardiographic Interpreter”), to name but a few.

With the incorporation of high-quality camera lenses in smartphones, one’s heart rate can be derived from the reflection of the skin, which alters with a change in blood flow, in one’s fingertip or face, as in the app “Cardio.”⁸ The camera and light functions can also be used to connect those too remote to medical help and could enable face-to-face consultations.

Smartphones come equipped with accelerometers and gyroscopes, allowing orientation in 6 *df*. This technology is used to turn the screen to landscape when tilting the smartphone and to measure device movement. This technology could be used to create 3-dimensional virtual tours of organs (eg, a tour of the heart’s chambers from inside the heart), a potentially powerful education tool. Finally, the light that most smartphones are equipped with, for a flash, is already used by many physicians as a torch to examine pupil size and reactivity to light.

With the continued development of apps by third parties, the uses of smartphones are endless. In early 2012, there were 40,000 apps available for download,⁹ of which 20,000 were “Medical” and “Healthcare & Fitness” apps, corresponding to 4% of the Apple store’s products.¹⁰

By the end of 2012, the number of apps had reached millions. Many of these apps will be of no use to clinicians. To prevent information overload, known to overwhelm the user and slow his or her productivity,¹¹ and time wasting, strategies will need to be implemented on an individual and organizational level. Search engines and critical evaluation of an app can help the individual choose to use an app. On an organizational level, regulation is required, which will be discussed later.

SMARTPHONE APPS IN CARDIOTHORACIC SURGERY

The main smartphone operating systems are Apple and Google. A search of their respective sites for apps related to cardiothoracic surgery yielded a varying number, depending on the search term used. The search terms were *cardiothoracic*, *cardiovascular*, *thoracic*, *thorax*, *cardiac*, *lung*, *heart*, *anatomy*, *surgery*, and variations thereof. Neither app site had the ability to search within specific categories. Therefore, the word *medical* was included in each search, helping to yield only apps arranged under this subheading. The searches of iTunes (Apple, Cupertino, Calif) and Play Store (Google, Mountain View, Calif) are displayed in Table 1.

Under the subheading “medical,” apps are mostly tailored to clinicians or medical students and include textbooks, dosage, risk factor calculations, radiography, surgical technique, annual conferences, and journal access. As evident in the results presented in Table 1, the more general (ie, less medical) the search term, the more results are yielded to include apps designed for the layperson. These include apps designed to monitor physiologic parameters, such as blood pressure, and explain medical concepts. The Play Store search yielded many more apps in each category than in iTunes, but fewer of these had involvement from the medical profession, as discussed later.

Both vendors provide descriptions of the apps to guide consumer choice. Furthermore, the Play Store allows the customer to sort search results by relevance or popularity, the latter derived from a Google algorithm that includes the number of downloads and customer ratings in its weighting scheme. iTunes provides a “featured” section that almost certainly uses a similar algorithm, as well as customer ratings, but the latter are often missing. Apple no longer provides download frequency information because it does not want to convey the potential financial gains made by itself or the app developer from popular apps.

Apparently, no objective rating of apps to guide customers exists. Others have attempted to quantify app quality in terms of both customer rating and named medical professional involvement. O’Neill and Brady¹² found that only 29% of colorectal apps had customer satisfaction ratings and 32% had named medical professional involvement. Visvanathan and colleagues¹³ found that only 34%

TABLE 1. Results from app search in iTunes and Play Store

Search term (followed by “medical”)	App provider (No. of apps)	
	Apple	Google
Cardiothoracic	7	193
Cardiothoracic surgery	3	70
Cardiac surgery	23	51
Cardiovascular	125	443
Thoracic	31	40
Thoracic surgery	6	26
Surgery	>700	>1000
Cardiac	178	>1000
Heart	>1000	416
Lung	131	183
Thorax	9	64
Anatomy	>800	>1000
Thoracic anatomy	6	26
Lung anatomy	10	33
Cardiac anatomy	6	58
Heart anatomy	41	46

Search performed March 5, 2013. *app*, Application.

of microbiology apps had named medical professional involvement. In an attempt to evaluate cardiothoracic apps, we performed a similar investigation, limited to 4 search terms closer to the fields included by cardiothoracic surgery. Each set of results was then manually searched for user rating and the involvement of a named medical professional, publisher, or professional society.

Table 2 shows the percentage of apps with some form of association with a named medical professional, publishers, or professional societies. In all categories, Apple apps have more medical professional involvement. Conversely, Google's apps have more user ratings for the apps. The numbers are confounded by the fact that many of the apps for either software platform appear in all 4 categories and some apps developed by professional societies appear several times within the same search group in different languages (Google). Even though user rating and the involvement of a named medical professional or publisher are useful indicators of app quality, they do not guarantee it. In addition, the cost of the smartphone and app further skews the download number, ratings, and developer input.

Clinicians need to know which apps contain reliable clinical information and perform accurate dosage calculations. To some extent, reliable names can guide them, such as known publishers releasing their textbooks in app form. Clinicians also need to know which apps contain accurate information, perform accurate calculations, and store data securely. Haffey and colleagues¹⁴ have already demonstrated a large discrepancy in the output of smartphone apps designed to calculate the equianalgesic dose of one opioid from another. This has serious implications for patient safety.

ISSUES SURROUNDING SMARTPHONE APPS

With the refinement and combination of varying smartphone technologies, apps will be created that are ever more sophisticated to facilitate tasks in our daily and professional lives. Along with clever programming and attachments, smartphones can have even more practical uses than the ones already used in the health care setting (eg, microphone technology advancement); combined with a bell attachment, they may one day rival a stethoscope for sound quality, cost, and capabilities. A working example of combination technology is the “Eye Phone,” pioneered by Bastawrous. It combines a smartphone with a modified ophthalmoscope, enabling retinal imaging in remote locations, communication with experts around the world, and text diagnosis.¹⁵ As devices become better and more multifunctional, smartphones could increase their area of application, improving patient care, enhancing learning, and cutting equipment costs for hospital trusts. These developments are promising, but the rapid development of smartphone technology has left security and regulatory issues unaccounted for. We have already discussed the lack of reliable rating of app quality and the potential patient harms because of interapp quality variability. This warrants urgent app regulation, and we discuss this issue alongside other concerns related to app security, technological development, and patient acceptance.

CLASSIFICATION AND REGULATION OF APPS

Part of the problem related to the regulation of apps used in medicine is how to classify them. Are they medical devices, adjuncts to medical education, or simply storage devices of information of varying sensitivity? Smartphone apps can be all those things, either separately or at once. The role of the app dictates the potential regulation, which has been overlooked.

On both sides of the Atlantic, there are laws and regulations pertaining to medical devices. The Food and Drug Administration (FDA) has several acts regarding medical device regulation, and the European Union (EU) has the Medical Devices Directive to the same effect. Both regulatory bodies include “stand-alone software,” used to analyze medical device data, under regulations for medical devices, but neither has yet made a decision on how to define and regulate smartphone apps.

In June 2009, the Swedish Medical Products Agency (Läkemedelsverket) presented “The Medical Products Agency's Working Group on Medical Information Systems,” recommending that “stand alone software and systems intended to, directly or indirectly, affect diagnosis, health care and treatment of an individual patient shall be regulated under a Product Safety Regulation.”¹⁶ The working group stated that “software intended for a medical purpose must be regarded as a ‘device’...” allowing it to be

TABLE 2. Evaluation of smartphone apps in iTunes and Play Store

Search term (followed by “medical”):	App provider (No. of apps)	
	Apple	Google
Cardiothoracic	7 User rating: 1 (14%) Named medical professional: 3 (43%) Publisher/professional society: 2 (29%)	193 User rating: 123 (64%) Named medical professional: 2 (1%) Publisher/professional society: 12 (6%)
Cardiothoracic surgery	3 User rating: 1 (33%) Named medical professional: 1 (33%) Publisher/professional society: 2 (66%)	70 User rating: 66 (94%) Named medical professional: 1 (1%) Publisher/professional society: 15 (21%)
Cardiac surgery	23 User rating: 2 (9%) Named medical professional: 10 (43%) Publisher/professional society: 5 (22%)	51 User rating: 30 (59%) Named medical professional: 1 (2%) Publisher/professional society: 2 (4%)
Thoracic surgery	6 User rating: 0 (0%) Named medical professional: 3 (50%) Publisher/professional society: 3 (50%)	26 User rating: 17 (65%) Named medical professional: 0 (0%) Publisher/professional society: 16 (62%)
Subtotal	39 (2 apps duplicated in search) User rating: 3 (8%) Named medical professional: 17 (44%) Publisher/professional society: 12 (31%)	340 User rating: 236 (70%) Named medical professional: 4 (1%) Publisher/professional society: 45 (13%)
Total (both providers)	379 User rating: 239 (63%) Named medical professional: 21 (6%) Publisher/professional society: 57 (15%)	—

app, Application.

governed by the EU law for medical devices.¹⁶ The European Medicines Agency, however, has still not reached a decision in the matter. In the United Kingdom, the Medicines and Healthcare Products Regulatory Agency remains ambivalent about whether smartphone apps are classified as discrete medical devices or not, although it seems likely that it will classify certain apps as per the Swedish working group's definition.¹⁰

In September 2013, the FDA issued “Mobile medical applications: Guidance for industry and Food and Drug Administration staff” with “nonbinding recommendations” on how software applied to the field of medicine should be regulated.¹⁷ The guidance applies to mobile medical apps defined as a mobile app that meets the FDA's definition of a device and is either intended to “be used as an accessory to a regulated medical device or to transform a mobile platform into a regulated medical device” by “performing patient-specific analysis and providing patient-specific diagnosis, or treatment recommendations.”¹⁷ This includes apps that display, store, analyze, or transmit patient-specific data or allow input thereof. It is hoped that these guidelines will serve as a guide to industry and the medical profession, and also to the EU, whose Medical Devices Directive could easily adopt many of its concepts.

In addition, the FDA guidelines expect distributors of mobile medical apps to cooperate with manufacturers in

the correction and potential market removal of apps found to pose a health risk and keep records of previous product corrections and removals.¹⁷ This is a difficult matter, both in the United States and the EU, because different laws govern safety correction action and pose practical problems of being able to turn off downloaded apps remotely to prevent harm.

More important, the FDA guidance excludes the following apps: apps used as personal health record systems, electronic copies of medical textbooks, reference material, and other teaching aids, which are solely for the educational benefit of medical students and clinicians. This has implications for integration of education and reference apps into patient electronic health records. Some NHS trusts have already incorporated links to the British National Formulary (unless classed as a medical device itself) within several electronic patient record systems, including discharge letter systems. For this to be developed further in the future, education and reference tool apps would need to be regulated and connections between servers made secure.

Meanwhile, the reliability of information in apps aimed at the education of clinicians and laypersons remains an issue. To ensure the quality of these apps would require cooperation between software developers, clinicians, royal colleges and professional societies, patient interest groups,

publishers, and the National Institute for Clinical Excellence and Health in the future. In the UK, the Department of Health is looking to encourage general practitioners to prescribe approved apps to help patients monitor and take control of their health,¹⁸ stressing the requirement of regulated content.

Data Security

With their technological versatility, smartphones and handheld tablets enable remote data collection, transferable to a central computer at a later date. Data collection apps produce issues surrounding data security and patient data confidentiality. Transfer of patient data via smartphones must comply with the same strict rules that apply to current electronic and hard copy transfer of patient data, as detailed by the Department of Health policies on confidentiality.¹⁹ It is, therefore, of utmost importance that patient data are secure, so that only those authorized can access it. This could be solved using encryption of data (eg, using virtual private network) and user passwords. NHS E-mail is encrypted and can be accessed on all smartphones that support encryption. Regarding mobile imaging, only individuals or organizations registered with the Information Commissioner as a data controller are allowed to take and send photographs.²⁰ Thus, using the smartphone for the sharing and transfer of images would involve strict data protection regulation. However, there has been no regulation in the United Kingdom pertaining specifically to smartphone publishing of medical images.²¹

In the vein of encryption, medicine can learn from the financial services industry. For several years, companies, in particular those in the financial sector, have used virtual private networks, encrypted web pages (https), and security tokens to allow employees access to sensitive data securely. Bank customers use these same technologies when accessing their bank account online or via an app on their smartphone. Security tokens take the form of card readers and key fobs, allowing electronic identification verification via regularly updated digital signatures. This prevents access to confidential information even if one or both devices are lost or stolen. Security tokens have already been used by general practitioners in Australia to access electronic health records stored on a remote central server.²²

Although clinicians could be equipped with such devices to securely access confidential patient information, an equivalent solution for the layperson accessing his blood pressure trend is less feasible. One could argue, however, that this type of information may not be sensitive because it cannot negatively affect the individual if it falls into the wrong hands.

A second issue concerning the use of smartphones for data collection is the technology required to enable resynchronization with the main server in the event of network failure. This becomes particularly challenging in

the event that several clinicians are editing the record of the same patient at the time of network failure. Evidently, there will be a huge demand for IT development. It follows that many experts will be required to develop and maintain this technology for the NHS. This is perhaps one of the greater challenges the NHS and other health care organizations must overcome.

Patient Acceptance

Smartphone apps have the potential to aid the delivery of safe and up-to-date care. They can also aid explanations of treatments and procedures to patients in consultations. Having said this, some patients experience that they vie for the physician's attention when they are "distracted" by a smartphone,²³ and other patients report distractions from mobile telephone and smartphone noise (eg, ringtones).²⁴ The issue herein is education, teaching current and future physicians how to incorporate information technology into daily practice, and for the medical profession to set clear guidelines about how and when mobile technology should be used. A distinction between and the separation of personal and professional mobile technology is one solution to this problem. King's College Hospital NHS Foundation Trust already uses mobile devices that have been disabled for verbal communication and only allow encrypted data handling by specific users. Alternatively, app development can be used to switch the telephone between private and business settings.

If the private and professional uses are allowed to merge, clinicians will increasingly use their personal equipment at work, known as bring-your-own-device. Already encountered in other sectors, this has huge implications for the health care sector. If allowed within medicine, it would need rigorous security measures to be put in place. Some NHS trusts are already exploring this option for their employees.²⁵

CONCLUSIONS

In the spirit of supporting innovation beneficial to cardiothoracic surgery trainees,²⁶ the authors set out to reliably present smartphone apps to enhance the education of this group. On further scrutiny of the subject, however, it was found not possible to do so transparently and objectively because of a lack of reliable comparative data.

Despite the benefits posed by smartphone app technology to the delivery of health care, patient outcome, and clinical and layperson education, there are still many unanswered questions related to the regulation of smartphone apps and how to safeguard patient-sensitive data. In an attempt to evaluate apps available to cardiothoracic surgery trainees, we have shown that regulation is missing. The authors do not want to stem the enthusiasm of using apps in medicine, but advise that apps be used with caution until systems of peer review and regulation are in place. Regulation is on

its way, but is slow, because of the complicated relationship between preexisting laws and relevant game players. Technological advances are rapid, but large changes and heavy investments in IT infrastructure and manpower are required to ensure that data security is optimal.

Once regulation is in place, however, questions remain regarding implementation in practice. It may be relatively easy to get industry to follow the regulations, but how does one ensure that physicians making apps are aware of the regulations? With the increasing presence of IT in the medical profession, its introduction into the medical curriculum may also be warranted.

We thank J. Omigie and T. Balla for their time, patience, and advice in creating this article.

References

1. NHS Hack Day 2012. Available at: <http://www.nhshackday.com>. Accessed August 15, 2012.
2. Kmietowicz Z. Mobile phone app from NHS "hack day" is set to transform handovers and task lists. *BMJ*. 2012;345:e5162.
3. Proffitt B. Prognosis for medical apps is guarded. August 15, 2012. Available at: <http://www.itworld.com/it-consumerization/289910/prognosis-medical-apps-guarded?page=0,0>. Accessed September 10, 2012.
4. Wales Deanery. Would you like to have free medical textbooks on your own iPhone/android smartphone as a new FY1? Available at: <http://www.walesdeanery.org/index.php/en/foundation-links/1357-would-you-like-to-have-free-medical-textbooks-on-your-own-iphone-android-smartphone-as-a-new-fy1.html>. Accessed September 10, 2012.
5. Brusco JM. Using smartphone applications in perioperative practice. *AORN J*. 2010;92:503-8.
6. Knowles MS. *The Modern Practice of Adult Education: Androgogy vs. Pedagogy*. New York, NY: Association Press; 1970.
7. Pedersen OB, Prestegaard K, Hjortdahl P, Holm HA. Livslang læring: hvordan lærer leger [Lifelong learning: how do physicians learn]? *Tidsskr Nor Laegeforen*. 1996;116:2684-8.
8. Nelson R. New iPhone app checks your heart rate by reading your face. August 10, 2012. Available at: <http://www.tecca.com/news/2012/08/10/cardio-heart-rate-app-iphone>. Accessed September 10, 2012.
9. Gold J. FDA regulators face daunting task as health apps multiply. *USA Today*. June 27, 2012.
10. Sherwin-Smith J, Pritchard-Jones R. Medical applications: the future of regulation. *Ann R Coll Surg Eng*. 2012;94:12-3.
11. Hall A, Walton G. Information overload within the health care system: a literature review. *HILJ*. 2004;21:102-8.
12. O'Neill S, Brady RR. Colorectal smartphone apps: opportunities and risks. *Colorectal Dis*. 2012;14:e530-4.
13. Visvanathan A, Hamilton A, Brady RR. Smartphone apps in microbiology: is better regulation required? *Clin Microbiol Infect*. 2012;18:E218-20.
14. Haffey F, Brady RR, Maxwell S. A comparison of the reliability of smartphone apps for opioid conversion. *Drug Safety*. 2013;36:111-7.
15. Medical Research Council. Max Perutz Science Writing Award 2012. Available at: <http://www.mrc.ac.uk/Newspublications/News/MRC008852>. Accessed September 25, 2012.
16. Medical Products Agency (Läkemedelsverket). Project summary document. The Medical Products Agency's Working Group on Medical Information Systems. June 2, 2009; revised January 18, 2010. Available at: http://www.lakemedelsverket.se/upload/foretag/medicinteknik/en/Medical-Information-Systems-Report_2009-06-18.pdf. Accessed March 7, 2013.
17. US Food and Drug Administration. Mobile medical applications: guidance for industry and Food and Drug Administration staff. September 25, 2013. Available at: <http://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm263366.pdf>. Accessed September 25, 2013.
18. Department of Health. GPs to 'prescribe' apps for patients. February 22, 2012. Available at: <http://www.dh.gov.uk/health/2012/02/apps>. Accessed September 10, 2012.
19. Department of Health. *33837/NHS Code of Practice: Confidentiality*. London, UK: Department of Health Publication; 2003.
20. Dala-Ali BM, Lloyd MA, Al-Abed Y. The uses of the iPhone for surgeons. *Surgeon*. 2011;9:44-8.
21. Payne KFB, Tahim A, Goodson AMC, Delaney M, Fan K. A review of current clinical photography guidelines in relation to smartphone publishing of medical images. *J Vis Comm Med*. 2012;35:188-92.
22. Dalley A, Lynch K, Feltham P, Fulcher J, Bomba D. The use of smart tokens to permit the secure, remote access of electronic health records. *Int J Electron Healthc*. 2006;2:1-11.
23. Payne P. Are smartphones distracting doctors? April 4, 2012. Available at: <http://www.imedicalapps.com/2012/04/smartphones-distracting-doctors>. Accessed September 17, 2012.
24. Visvanathan A, Gibb AP, Brady RR. Increasing clinical presence of mobile communication technology: avoiding the pitfalls. *Telemed J E Health*. 2011;17:656-61.
25. National Health Service. Informatics Merseyside. Bring your own device initiative. Available at: http://www.imerseyside.nhs.uk/Innovations/bring_your_own_device_initiative.aspx. Accessed March 5, 2013.
26. Chitwood WR. Developing and financing new technology. *JTCVS*. 2002;124:223-30.