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# Use of Smartphones in Hospitals

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# USE OF SMARTPHONES IN HOSPITALS

## ABSTRACT

Mobile technology has begun to change the landscape of the medical profession with more than two-thirds of physicians regularly using smart phones. Smartphones have allowed healthcare professionals and the general public to communicate more efficiently, collect data and facilitate the clinical decision making. The methodology for this study was a qualitative literature review following a systematic approach of the smartphone usage among physicians in hospitals. Fifty-one articles were selected for this study based on inclusion criteria. The findings were classified and described into seven categories: use of smartphone in obstetrics, pediatrics, surgery, internal medicine, radiology, and dermatology which were chosen based on the documented use of smartphone application in different healthcare practices. A last section of patient safety and issues with confidentiality is also described. This study suggest that smartphones have been playing an increasingly important role in healthcare. Medical professionals have become more dependent upon medical smartphone applications. However, concerns of patient safety and confidentiality will likely lead to increased oversight of mobile device use by regulatory agencies and accrediting bodies.

**Key Words:** Smartphone, m-health, Hospitals, physicians, patient confidentiality

## INTRODUCTION

Advanced telecommunications, portable computation and combined functionality of a pager, a cell phone and a Personal Digital Assistants (PDA) have been replaced by a single handheld device called a “smartphone”, which is becoming extremely well-liked among healthcare

professionals, as well as the general public.<sup>1</sup> Furthermore, smartphones are capable of administrating third-party software.<sup>2</sup> The number of smartphone users has been growing rapidly among the healthcare professionals. The most modern invention of smartphones are increasingly viewed as handheld computers rather than as phones, due to their prevailing on-board computing ability, large memories, big screens and open operating systems that encourage application development.<sup>3</sup> Health and healthcare smartphone applications (apps) available in the market include rising trends and marketplace uptake.<sup>4</sup>

Development and availability of medical apps have been a key milestone that can effectively change the medical world. There has been a massive increase in the number of consumers of smartphone apps downloaded over the past two years, from 300 million downloaded in 2009 to five billion in 2010.<sup>5</sup> Various smartphones have different Operating Systems (OS). Medical apps are specific to the OS. Platforms available today include Apple iOS, Android, Windows, Symbian, and RIM BlackBerry. Hence, all apps may not be available on all smartphones with different OS.<sup>4</sup>

Apps are available addressing all possible domains of medical science like healthcare, medical education, training, research, medical literature and latest medical update for almost all specialties in the field of medicine.<sup>6</sup>

The healthcare system is very mobile in nature, connecting numerous medical locations such as inpatient wards, clinics, outpatient services, operating rooms, emergency departments, Intensive Care Units (ICUs), laboratories, and many more.<sup>7,8,9</sup> As such, functioning in the healthcare system requires wide mobility of healthcare professionals as well as communication and association among various individuals, together with their colleagues and patients.<sup>10</sup> Healthcare providers primarily have used pagers for mobile communication until the extensive

availability of cell phones in the 2000s.<sup>11</sup> The advent of mobile PDA's during earlier years, i.e. 2003, enabled healthcare professionals to systematize their contacts and calendars electronically.<sup>12</sup> Several preceding studies have evaluated the use of mobile phones to sustain healthcare and public health interventions, particularly in the collection and collation of data for healthcare research and as used in support of medical and healthcare education and clinical practice in the society.<sup>13,14</sup>

Mobile technology has changed the landscape of the medical professions, as the majority of providers' desire for decision support and current clinical information at the point of care increases.<sup>9,15</sup> Several surveys have determined that more than 80% of physicians and Certified Registered Nurse Anesthetists used smartphones.<sup>16,17</sup> Smartphones have offered physicians a less cumbersome format for Health Information Technology (HIT) without the imposition of a large financial burden, by combining the features of a cellular telephone, pager, and a PDA. Although some have reported that smartphones may be more of an interruption than a help.<sup>11,18,19</sup> Nonetheless, physicians have moved away from the traditional pagers to smartphone devices, enhancing the efficiency within healthcare organizations by allowing improved time management and communication between other medical colleagues.<sup>20,21,22,23</sup>

Within in the healthcare population, the utilization of smartphones has the potential to have a positive impact upon patient care. Specially, by providing immediate access to medical and health information, because of which it can lead to improved-decision making and reduced number of medical errors, improved communication between hospital medical staff and enhanced telemedicine capability.<sup>24,25,26</sup>

Some studies have highlighted the successful use of mobile phones to support telemedicine and remote healthcare in developing countries, with examples including their use in off-site medical diagnosis.<sup>27,28</sup>

The purpose of this study was to analyze how medical practitioners and medical educators can benefit from the use of smartphone technology in hospitals.

## METHODOLOGY

The methodology for this study was a qualitative literature review following the principles of a systematic search. The Marshall University library was used for full text articles, utilizing the PubMed, EbscoHost, ProQuest, MEDLINE, and Google Scholar databases. Google was used when articles could not be located through the above data bases. Key terms used in the search included ‘Smartphones’ OR ‘Mobile phones’ OR ‘m-health’, AND ‘hospitals’, OR ‘physicians’, OR ‘access to healthcare’ OR ‘patients’. The search was limited to articles published 2005 through 2014 as smartphone and tablet technology has only recently become dominant. Articles were limited to the English language.

Primary and secondary data were included from original articles, research studies and reviews. Relevant articles were selected after review of abstracts was performed. Out of 74 total articles, 51 references were chosen for this research based on inclusion criteria. Abstracts of the sources were reviewed first to determine if the information presented in the articles was related to the study. The data was analyzed and categorized based on the findings. This search was completed by MM, NT and SA, NM and validated by AC who acted as a second reader and also double checked if references met the research study inclusion criteria.

The approach for this research study followed systematic search steps and research framework utilized by Hogan and his colleagues.<sup>29</sup> The use of the conceptual framework in the

current study is appropriate as the focus is on the use of smartphone applications in the context of care among physicians in hospitals. Figure 1 depicts the process of using smartphone apps by healthcare professionals. To research how smartphone apps can help to improve the healthcare delivery system in the hospital, it is first necessary to recognize the various users of medical apps and the healthcare practices that can adopt the usage of these apps. Then different medical apps can be identified to deliver a high quality of healthcare and improved health outcomes (Figure 1).

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INSERT FIGURE 1 ABOUT HERE

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## RESULTS

Different methods can be followed for the development of mobile apps. However, its implementation in different platforms has some restrictions, implying that an application has to be developed for each platform or follow another approach which facilitates the process of creating applications.<sup>30</sup>

### *Use of Smartphone in Obstetrics*

The use of obstetrics smartphone's applications have enabled a better prediction of the expected date of delivery for all pregnant women monitored by obstetricians, allowing the physicians to manage personal data, medical history and important dates related to each pregnant woman, triggering reminders on their mobile device for the relevant dates.<sup>31</sup> Valente, Braga, Machado, Santos, and Abelha (2013) developed a new mobile application, compatible with Android and iOS that aimed to support obstetric practice.<sup>32</sup> The application's main indication was to enable the management of all pregnant women accompanied by an obstetrician, facilitate a more reliable prediction of the expected date of birth and gestational age, and provide an appointment book of all relevant dates of their pregnancy. In addition, it has been a useful

functionality that has allowed creating records for each mother, enabling the storage of data relative to personal information, family clinical history, and pregnancy related information.<sup>32</sup>

### *Use of Smartphone in Pediatrics*

Hawkes, Walsh, Ryan, and Dempsey (2013) reported on the usage of smartphones among trainees in pediatrics to increase trainees knowledge and improve their procedural skills in newborn intubation by the implementation of a smartphone neonatal intubation instructional application (NeoTube).<sup>33</sup> Twenty pediatric trainees including 12 fellows and 8 residents participated in this study. The trainees completed a knowledge based questionnaire on neonatal intubation before and after viewing the NeoTube application. In addition, the intubation procedure on newborn manikin model was recorded. In this study, the results of questionnaire scores and recorded sessions were compared before and after viewing the app. It was found that the median of the questionnaire scores increased from 18.5 seconds to 31 seconds, calculation scores rose from 6 seconds, skill scores went up from 11 seconds to 12.5 seconds, and the duration of intubation decreased from 39 seconds to 31 seconds following the usage of the application. There was a significant positive change in the duration of professional training for procedure performance after viewing the app.<sup>33</sup>

Another study in 2012 reviewed the available smartphone apps relevant to pediatrics and neonatal care. Applications were identified according to their purpose of use and classified into five categories: reference and education, medical calculators, drug information, epidemiology, and recent development in the medical field [news]. Out of the 46 applications it was found that 27 applications used for reference and education, 8 were medical calculators/convertors, and 5 for drug information (Table1). Only 3 pediatrics-related apps were included. The pediatrics apps were Pediatrics central, Essentials of pediatrics radiology, and Phototherapy calculator. The rest

of the apps could be used by all other clinical professionals including physicians, nurses, and pharmacists (Table 1).<sup>34</sup>

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A similar study was conducted in 2012 to examine smartphone apps (iPhones and iPads) that assisted anesthetic management of pediatric patients. Bhansali and Armstrong (2012) identified ten apps related to pediatric anesthesia which were: Peds anesthesia, Paeds ED, Drug calc, Paediatric emergency drugs, Pedi safe, AnaPaed, Pediatric, Peds Meds, PICU calculator, and Drug doses (Table 2).<sup>35</sup> Six of these apps provided an estimation of child's weight based on age by using several formulas and weight charts to give a range of answers for each age entered. Moreover, all the apps were able to provide drug doses within the dose ranges quoted in the British National Formulary for Children.<sup>35</sup>

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In 2013, Ling and his colleagues used a statistical learning method to create and validate a Kawasaki Disease (KD) algorithm to be used with clinical and laboratory data related to KD to improve the accuracy of diagnosis. The aim was to facilitate real-time KD diagnosis by allowing physicians to access the data remotely via a smartphone application. Several models were trained to use the computerized algorithm with 276 patients who have KD and 243 patients who shared some features of Kawasaki Disease (FCs) and verified with 136 KD patients and 121 FCs using medical data, lab results, or combination of both. Training and testing sets were developed to determine the values of diagnostic tests performed through smartphones for medical and lab results data combined. The KD scoring method classified into subcategories with low febrile



illness diagnosis, intermediate, and high KD diagnosis scores. Combining both medical and lab test results, the algorithm diagnosed 81.2% of all training sets and 74.3% of all testing KD patients in the high score group and 67.5% of all training and 62.8% of all testing FCs in the low score group.<sup>36</sup>

### *Use of Smartphone in Surgery*

The studies that have evaluated the use of smartphones during surgery have been limited. According to Franko (2011), even though the use of smartphones and their apps was diffused among orthopedics physicians in academic centers, apps with a high rank and related to orthopedics surgery were rarely available, and the apps that were available did not coincide with the most desired categories by surgeons and residents.<sup>37</sup> This study was conducted with orthopedic residents and surgeons in the U.S. and revealed that 53% of all respondents to the survey who had smartphones (n=476) already used apps in clinical practices.

Another research by Franko and Bhola (2011) on the iPad apps for the orthopedic surgeons found that from the 34 apps designed for orthopedic surgeons and trainees, 32% were focused in clinical practice, 26% had a patient teaching focus, 26% were sponsored by industry, and only 6% had a primary focus on education/training.<sup>38</sup> Among these apps, 47% were general and covering a range of orthopedic specialties, 32% were designed for spine providers, 12% for arthroplasty, 3% for hand, 3% for foot and ankle, and 3% for trauma (Figure 2).

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### *Use of Smartphone in Internal Medicine*

The role of telemedicine has become more important to promptly coordinate the efforts of the stroke team especially with the increase of demand for fast accurate diagnosis and treatment of strokes.<sup>39</sup> Several studies had used smartphones for assisting clinicians to diagnose and treat stroke. Takao, Murayama, Ishibashi, Karagiozov, and Abe (2012) created a system called “i-Stroke” that allowed physicians to rapidly access patients’ clinical data and diagnostic images in and out of the healthcare facility through their smartphones.<sup>40</sup> The i-Stroke transferred clinical data, CT, MR, angiographic, intraoperative images, and medical staffs’ opinion in real time. A pilot application of the i-Stroke system successfully transferred clinical information for 55 patients who were admitted by ambulances and 9 patients who were admitted as walk-ins. The patient’s transfer distance ranged between 1 and 20 km. Moreover, the system effectively allowed clinicians to discuss patients’ health condition using a Twitter system.<sup>40</sup>

A study published in 2012 reported new advantages to smartphones. A health monitoring system based on the smartphone was developed. A small and low-power-consuming Biosignal Monitoring Unit (BMU) measured electrocardiogram (ECG), Photoplethysmogram (temperature, oxygen saturation, energy expenditure, and location information. The 2.4 GHz Bluetooth network in the BMU communicated with a smartphone making it an efficient personal health monitoring system was developed and tested successfully for multiple users.<sup>41</sup>

Another study in 2011 described a new opportunity for mobile devices users, the eCAALYX mobile application. The eCAALYX Mobile Application has been developed under the scope of the eCAALYXEU-funded project (Enhanced Complete Ambient Assisted Living Experiment, 2009-2012), which focused on building a remote monitoring system targeting older people with multiple chronic diseases. Patients’, care givers’ and clinicians’ involvement was extensive throughout the prototype design, deployment and testing, and clinical trial phases of

the project. The main purpose of the eCAALYX Mobile Platform was to act as an easy information based link between the wearable health sensors used by the older person and the health professionals' Internet site, by informing the patients and health professionals about alerts and measurements obtained from sensors and the geographic location through the use of the smartphone GPS of the user. Also, the mobile platform was able to reason with the raw sensor data which identified higher level information, which included easy-to-detect problems including tachycardia and signs of respiratory infections, based on established medical knowledge. Additionally, a user interface was also offered, which allowed the user to be able to evaluate the most recent medical details obtained from sensors, perform new measurements, and communicate with the caretakers.<sup>4</sup>

#### *Use of Smartphone in Radiology*

Demaerschalk and his colleagues (2012) evaluated the level of interpretation agreement on non-contrast CT brain scan for patients with stroke between vascular neurologists who used ResolutionMD app, radiologists who used a Picture Archiving and Communications System (PACS), and autonomous tele-stroke adjudicators who used a desktop viewing system (QREADs). In this study, 53 patients with stroke were participated and their CT scans were evaluated by neurologists, radiologists, and autonomous adjudicators. It was concluded that there were an excellent level of agreement between neurologists using ResolutionMD by neurologists with radiologists who used PACS and those of autonomous tele-stroke adjudicators using a desktop viewer.<sup>42</sup>

The use of smartphone applications among radiologists have been increased according to the radiology apps that available in the market. Al-Hasani, Abboudi, Ninan, Shaygi, and Roobottom (2013) categorized radiology apps into three classifications: viewing software,

references and education apps, and smartphone based ultrasound device.<sup>43</sup> Viewing software included apps that allowed radiologists and other clinicians to view radiology images remotely by using their smartphones or tablets. Under this category, four apps were reviewed, but only three were approved by FDA to use for diagnosis which were: Mobile MIM, Osirix, and Resolution MD. The second category was for radiology teaching purposes and five apps was included. Radiology Assistant and iRefer apps offer peer-reviewed articles and references images on radiology related topics. Radiology Passport app taught clinicians about the potential risk of radiation exposure. SonoAccess app provided videos and documents with instructions for ultrasound procedures. Rad-Rx was developed for radiologists to assist them with emergency conditions by providing rapidly access to algorithms for treating allergic reactions. The use of mobile ultrasound device attached to a smartphone was the last category and there was only one app recognized. That app was “MobiUS” and was approved by FDA.<sup>43</sup> Figure 3 show percentage of radiology apps under each category. Most of apps that were selected were used for radiology teaching purposes (Figure 3).

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### *Use of Smartphone in Dermatology*

Another clinical practice that attract the development of smartphone apps has been dermatology. According Brewer et al., 2013, there were 229 smartphone apps that related to dermatology practice.<sup>44</sup> The apps were classified into several categories: general dermatology references (61), self-surveillance/diagnosis (41), disease guides (39), educational aids (20), sunscreen/UV recommendations (19), calculators (12), tele-dermatology (8), conferences (6),

journals (6), photograph storage/sharing (5), dermoscopy (2), pathology (2), and others (8).<sup>44</sup>

Figure 4 illustrated by percentage of dermatology apps under each category (Figure 5).

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### *Regulation and Patient Safety of Smartphone Utilization in Medicine*

As the use of smartphones and medical-related applications increases, the need for regulation becomes a primary concern. The Emergency Nurses Association has recognized the potential for software defects and inaccurate content in medical smartphone applications.<sup>45</sup> There is no required review of medical applications by medical organizations or physicians, making professional review of such applications voluntary on the part of developers and thereby increasing user liability.<sup>37</sup> The Food and Drug Administration (FDA) has taken a risk-based approach to regulation of mobile medical apps. The FDA focuses on apps that “are intended to be used as an accessory to a regulated medical device or transform a mobile platform into a regulated medical device”.<sup>46</sup>

Although the benefits of smartphone use in medicine are numerous, it is necessary to recognize the potential impact on patient safety. Development of security guidelines is essential, as patient confidentiality arises as a major concern with regards to medical use of smartphones.<sup>47</sup> Smartphone functions, such as texting, are of concern to accrediting bodies. The Joint Commission has stated that it is unacceptable for a providers to text patient orders, stating that it is not possible to identify the individual sending the text and there is no method to archive messages as validation of medical records.<sup>48</sup> In a position statement regarding mobile device use, the American Association of Nurse Anesthetists recognized that while the use of mobile

devices can enhance patient care, the lack of device and application regulation regarding validity and content is a major concern.<sup>49</sup> In addition to the distraction often observed with users of mobile devices, video and audio capabilities of mobile devices also raise question with regards to patient confidentiality and privacy.<sup>49</sup> The camera found on many mobile devices raises issues regarding protected health information; the misuse of a device is both a security and privacy risk, especially in a society so entwined with social media.<sup>45</sup>

## DISCUSSION

The use of smartphones and their apps in daily medical practice generally is premature even though communication and technology within the hospital has progressed significantly over the years in term of reducing costs and improving quality.<sup>50</sup> However, there is a significant and growing interest in the use of smartphones and their accessibility, acceptability and potential efficacy in medical field, which is a consequent reflection of the mostly growing interest in smartphone applications worldwide.

The use of these devices appears to be growing rapidly due to the real-time advantages they offer in making critical clinical decisions, although significant potential problems exist with the use of this approach. There may be difficulty obtaining and verifying accurate and valid results versus traditional sources, but this problem may be reduced by using only trusted internet sources; i.e., ones which have been peer reviewed. Similarly, many physicians are used to simply “Googling” a question, which may not result in an authoritative answer.<sup>51</sup> Healthcare professionals may make a critical decision based on information from an app. This exposes the importance of having accurate and reliable mobile medical apps used in healthcare settings. Addressed literature of the mobile medical apps accuracy has been limited, and already existed literature was often highly specialized and not necessarily generalizable to all medical apps.<sup>52</sup>

Furthermore, the accuracy of most of the apps has not been determined statistically. Rather, the apps have been reviewed in each of the healthcare field by using available information in the app stores.

As the use of smartphones evolves and continues to increase, patient safety issues evolve, the regulation of mobile device applications is likely to become an area of emphasis in accreditation. Issues of patient safety and confidentiality will likely lead to increased oversight of mobile device use by regulatory agencies and accrediting bodies. The development of most apps has been done by commercial companies aiming for profit and leaving the safety of these apps dubious. Furthermore, deskilling clinical staff by becoming over reliant on apps is another concern about the use of such apps. Another concern is the negative effect on physician-patient interactions stemming from the use of smartphones at the bedside.<sup>53</sup>

It is expected that medical professionals will become more dependent upon these kinds of devices as time goes on. The findings of the present study suggested that the future use of smartphones by physicians, residents and health educators will rely on these devices and their medical applications more than previous generations.<sup>54</sup> It seems likely that these individuals, who have been exposed to the advantages offered by the use of smartphones, will continue using this mobile technology in medical practice in particular. Continuing education for physicians could be developed for the clinical use of smartphone, and younger physicians in training who have been exposed to smartphones as a learning mechanism can acknowledge the utility of this approach.

Smartphones have been useful tools in various industries. Smartphones provide advanced communication, improve the delivery of services, and reduce transmission errors which would lead to economic growth of countries around the world.<sup>55</sup> According to Entner and Analytics

(2012), the use of smartphones would improve the productivity by diminishing traveling time, enhancing logistics, and accelerating decision-making.<sup>56</sup> It has been estimated that the healthcare industry productivity was risen by \$ \$11.2 billion it is expected that the productivity in healthcare will increase \$305.1 billion within the next 10 years.

There were several limitations of this literature review. First, the number of studies and their nature: most of the studies found in use of smartphones were of patient-orientation nature, and fewer were healthcare professionals, especially physicians, oriented. Another constraint faced is due to the essential intention of this review was to use as up-to-date as possible studies, but this was almost impossible with the rapid and evolving elixir of this type of technology. Other limitations included search strategy chosen, and research and publication bias cannot be ruled out.

The findings suggest that some smartphone medical applications are effectively improving the delivery of healthcare services; however, the demand for more studies of these applications is warranted. Also, these results suggest that despite the improvement of clinical diagnosis and management aspects obtained by providing support for healthcare professionals through the use of some apps, other apps had negative effects—especially, the use of photos for diagnosis purposes that rely on mobile technology. Therefore, more studies are needed to evaluate the ability of using smartphone apps in hospitals. The quality of these studies should be emphasized on. Furthermore, the studies should be undertaken in both limited resources and leading healthcare facilities.<sup>57</sup>

## CONCLUSION

This study suggest that smartphones have been playing an increasingly important role in healthcare. Medical professionals have become more dependent upon medical smartphone



applications. However, concerns of patient safety and confidentiality will likely lead to increased oversight of mobile device use by regulatory agencies and accrediting bodies.

## REFERENCES

1. Unhelkar, B. (2006). *Handbook of research in mobile business: technical, methodological and social perspectives*. Hershey, PA, IGI Global.
2. Coney, L., Cois, A., & Rosenberg, B. (2012). Smartphones and Election 2012. In *epic.org*. Retrieved November 2, 2014, from <http://epic.org/privacy/voting/Smartphones-and-Election-2012.pdf>
3. Falaki, H., Mahajan, R., Kandula, S., Lymberopoulos, D., Govindan, R., & Estrin, D. (2010). Diversity in smartphone usage. In *Proceedings of the 8th international conference on Mobile systems, applications, and services* (pp. 179-194). ACM.
4. Boulos, M. N., Wheeler, S., Tavares, C., & Jones, R. (2011). How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX. *Biomedical engineering online*, 10(1), 24.
5. White House (2012). *The Economic Benefits of New Spectrum for Wireless Broadband*. In. Retrieved November 2, 2014, from [http://www.whitehouse.gov/sites/default/files/cea\\_spectrum\\_report\\_2-21-2012.pdf](http://www.whitehouse.gov/sites/default/files/cea_spectrum_report_2-21-2012.pdf)
6. Gupta, G. (2013). Are Medical Apps the future of medicine?. *Medical journal, Armed Forces India*, 69(2), 105.
7. Bardram, E. (2005). Activity-based computing: support for mobility and collaboration in ubiquitous computing. *Personal and Ubiquitous Computing*, 9(5), 312-322.
8. Chatterjee, S., Chakraborty, S., Sarker, S., Sarker, S., & Lau, F. Y. (2009). Examining the success factors for mobile work in healthcare: a deductive study. *Decision Support Systems*, 46(3), 620-633.
9. Mosa, A. S. M., Yoo, I., & Sheets, L. (2012). A systematic review of healthcare applications for smartphones. *BMC medical informatics and decision making*, 12(1), 67.
10. Ventola, C. L. (2014). Mobile devices and apps for health care professionals: uses and benefits. *Pharmacy and Therapeutics*, 39(5), 356.
11. Burdette, S. D., Herchline, T. E., & Oehler, R. (2008). Practicing medicine in a technological age: using smartphones in clinical practice. *Clinical infectious diseases*, 47(1), 117-122.
12. Garritty, C., & El Emam, K. (2006). Who's using PDAs? Estimates of PDA use by health care providers: a systematic review of surveys. *Journal of medical Internet research*, 8(2).

13. Blaya, J. A., Fraser, H. S., & Holt, B. (2010). E-health technologies show promise in developing countries. *Health Affairs*, 29(2), 244-251.
14. Lindquist, A. M., Johansson, P. E., Petersson, G. I., Saveman, B. I., & Nilsson, G. C. (2008). The use of the Personal Digital Assistant (PDA) among personnel and students in health care: a review. *Journal of medical Internet research*, 10(4).
15. Baumgart, D. C. (2011). Smartphones in clinical practice, medical education, and research. *Archives of internal medicine*, 171(14), 1294-1296.
16. Johns, HJ. (2012). *A Prospective Survey Research Study: CRNAs and Smartphone Use* (Unpublished doctoral dissertation). South Charleston, WV, Marshall University.
17. O'Reilly, K. B. (2012, January 2). Doctors Have to Manage Smartphone Distractions. In *American Medical News*. Retrieved September 21, 2014, from <http://www.amednews.com/article/20120102/profession/301029950/1/>
18. Ross, S., & Forgie, S. (2012). Distracted doctoring: Smartphones before patients?. *Canadian Medical Association Journal*, 184(12), 1440-1440.
19. Sarasohn-Khan, J. (2010). How Smartphones Are Changing Health Care for Consumers and Providers. In *California HealthCare Foundation*. Retrieved September 20, 2014, from <http://www.chcf.org/~media/MEDIA%20LIBRARY%20Files/PDF/H/PDF%20HowSmartphonesChangingHealthCare.pdf>
20. Putzer, G. J., & Park, Y. (2012). Are physicians likely to adopt emerging mobile technologies? Attitudes and innovation factors affecting smartphone use in the southeastern United States. *Perspectives in health information management/AHIMA, American Health Information Management Association*, 9(Spring).
21. Sheth, N., & Kane, Y. W. (2009, October 8). Smart-Phone Makers Call the Doctor. In *The Wall Street Journal*. Retrieved September 21, 2014, from <http://online.wsj.com/articles/SB125487806705169673>
22. Ozdalga, E., Ozdalga, A., & Ahuja, N. (2012). The smartphone in medicine: a review of current and potential use among physicians and students. *Journal of medical Internet research*, 14(5).
23. Voalté (2010). *Smart hospitals: Embracing smartphones at the point of care*. In Retrieved September 21, 2014, from <http://www.voalte.com/uploads/docs/Smart%20Hospitals.pdf>
24. Armstrong, D. G., Giovinco, N., Mills, J. L., & Rogers, L. C. (2011). FaceTime for Physicians: Using Real Time Mobile Phone-Based Videoconferencing to Augment Diagnosis and Care in Telemedicine. *Eplasty*, 11.

25. Aziz, S. R., & Ziccardi, V. B. (2009). Telemedicine using smartphones for oral and maxillofacial surgery consultation, communication, and treatment planning. *Journal of Oral and Maxillofacial Surgery*, 67(11), 2505-2509.
26. Prgomet, M., Georgiou, A., & Westbrook, J. I. (2009). The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. *Journal of the American Medical Informatics Association*, 16(6), 792-801.
27. Kaplan, W. A. (2006). Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries. *Global Health*, 2(9), 1-14.
28. Martinez, A. W., Phillips, S. T., Carrilho, E., Thomas III, S. W., Sindi, H., & Whitesides, G. M. (2008). Simple telemedicine for developing regions: camera phones and paper-based microfluidic devices for real-time, off-site diagnosis. *Analytical Chemistry*, 80(10), 3699-3707.
29. Hogan, T. P., Nazi, K. M., Luger, T. M., Amante, D. J., Smith, B. M., Barker, A., et al. (2014). Technology-Assisted Patient Access to Clinical Information: An Evaluation Framework for Blue Button. *Journal of Medical Internet research protocols*, 3(1).
30. König-Ries, B. (2009). Challenges in mobile application development. *it-Information Technology Methoden und innovative Anwendungen der Informatik und Informationstechnik*, 51(2), 69-71.
31. Farag, S., Chyjek, K., & Chen, K. T. (2014). Identification of iPhone and iPad Applications for Obstetrics and Gynecology Providers. *Obstetrics & Gynecology*, 124(5), 941-945.
32. Valente, S., Braga, J., Machado, J., Santos, M., & Abelha, A. (2013). The impact of mobile platforms in obstetrics. *Procedia Technology*, 9, 1201-1208.
33. Hawkes, C. P., Walsh, B. H., Ryan, C. A., & Dempsey, E. M. (2013). Smartphone technology enhances newborn intubation knowledge and performance amongst paediatric trainees. *Resuscitation*, 84(2), 223-226.
34. Sondhi, V., & Devgan, A. (2013). Translating technology into patient care: Smartphone applications in pediatric health care. *Medical Journal Armed Forces India*, 69(2), 156-161.
35. Bhansali, R., & Armstrong, J. (2012). Smartphone applications for pediatric anesthesia. *Pediatric Anesthesia*, 22(4), 400-404.
36. Ling, X. B., Kanegaye, J. T., Ji, J., Peng, S., Sato, Y., Tremoulet, A., et al. (2013). Point-of-care differentiation of Kawasaki disease from other febrile illnesses. *The Journal of pediatrics*, 162(1), 183-188.

37. Franko, O. I. (2011). Smartphone apps for orthopaedic surgeons. *Clinical Orthopaedics and Related Research*®, 469(7), 2042-2048.
38. Franko, O. I., & Bhola, S. (2011). iPad Apps for Orthopedic Surgeons. *Orthopedics*, 34(12), 978-981.
39. Schwamm, L. H., Audebert, H. J., Amarenco, P., Chumbler, N. R., Frankel, M. R., George, M. G., et al. (2009). Recommendations for the Implementation of Telemedicine Within Stroke Systems of Care A Policy Statement From the American Heart Association. *Stroke*, 40(7), 2635-2660.
40. Takao, H., Murayama, Y., Ishibashi, T., Karagiozov, K. L., & Abe, T. (2012). A new support system using a mobile device (smartphone) for diagnostic image display and treatment of stroke. *Stroke*, 43(1), 236-239.
41. Lee YG, Jeong WS, Yoon G. Smartphone-based Mobile Health Monitoring. *Telemed J E Health*. 2012;18(8):585-590.
42. Demaerschalk, B. M., Vargas, J. E., Channer, D. D., Noble, B. N., Kiernan, T. E. J., Gleason, E. A, et al. (2012). Smartphone teleradiology application is successfully incorporated into a telestroke network environment. *Stroke*, 43(11), 3098-3101.
43. Al-Hasani, H., Abboudi, H., Ninan, T., Shaygi, B., & Roobottom, C. (2013). Smartphone Applications for the Radiologist. *Open Journal of Radiology*, 2013.
44. Brewer, A. C., Endly, D. C., Henley, J., Amir, M., Sampson, B. P., Moreau, J. F., & Dellavalle, R. P. (2013). Mobile applications in dermatology. *JAMA dermatology*, 149(11), 1300-1304.
45. Emergency Nurses Association (ENA). *Mobile Electronic Device Use in The Emergency Setting Position Statement*. 2013. Retrieved from <http://www.ena.org/about/position/position/Pages/Default.aspx> Accessed January 16, 2015.
46. Food and Drug Administration (FDA). *Mobile Medical Applications*. 2014. Retrieved from <http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ConnectedHealth/MobileMedicalApplications/ucm255978> Accessed January 16, 2015
47. Charani, E., Castro-Sanchez, E., Moore, Luke SP, and Holmes, A.. Do Smartphone Applications in Healthcare Require a Governance and Legal Framework? It Depends on the Application. 2014. BMC Med. 2014; 12:29. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3929845/> Accessed January 16, 2015

48. The Joint Commission (JCAHO). *Standards Frequently Asked Questions*. 2011. Retrieved from [http://www.jointcommission.org/mobile/standards\\_information/jcfaqdetails.aspx?StandardsFAQId=401&StandardsFAQChapterId=79](http://www.jointcommission.org/mobile/standards_information/jcfaqdetails.aspx?StandardsFAQId=401&StandardsFAQChapterId=79) Accessed January 16, 2015
49. American Association of Nurse Anesthetists [AANA]. Mobile Device Use Position Statement. 2013. Retrieved from <http://www.aana.com/resources2/professionalpractice/Pages/Mobile-Device-Use.aspx> Accessed January 16, 2015
50. Dala-Ali, B. M., Lloyd, M. A., & Al-Abed, Y. (2011). The uses of the iPhone for surgeons. *The surgeon*, 9(1), 44-48.
51. Hall, S. D. (2013, December 31). Why telemedicine is natural for 'next generation' of docs. In *FierceHealthIT*. Retrieved November 1, 2014, from [http://www.fiercehealthit.com/story/why-telemedicine-natural-next-generation-docs/2013-12-31?utm\\_source=rss&utm\\_medium=rss](http://www.fiercehealthit.com/story/why-telemedicine-natural-next-generation-docs/2013-12-31?utm_source=rss&utm_medium=rss)
52. Lewis, T. L., & Wyatt, J. C. (2014). Mhealth and mobile medical apps: A framework to assess risk and promote safer use. *Journal of medical Internet research*, 16(9).
53. Moore, S., Anderson, J., & Cox, S. (2012). Pros and cons of using apps in clinical practice: Smartphones have the potential to enhance care but, say Sally Moore and colleagues, healthcare apps are not regulated, making it hard for nurse managers to be certain that those available are accurate, reliable and safe. *Nursing Management*, 19(6), 14-17.
54. Kagan, J. M. (2013, February 10). Good, not-so-good changes face doctors, patients today. In *Medical Economics*. Retrieved November 1, 2014, from <http://medicaleconomics.modernmedicine.com/medical-economics/news/user-defined-tags/jeffrey-kagan/good-not-so-good-changes-face-doctors-patient?page=full>
55. West, D. (2012). How mobile devices are transforming healthcare. *Issues in technology innovation*, 18, 1-14.
56. Entner, R., & Analytics, R. (2012). The wireless industry: The essential engine of U.S. economic growth. *Recon Analytics*, 30-33.
57. Free, C., Phillips, G., Watson, L., Galli, L., Felix, L., Edwards, et al. (2013). The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. *PLoS medicine*, 10(1), e1001363.

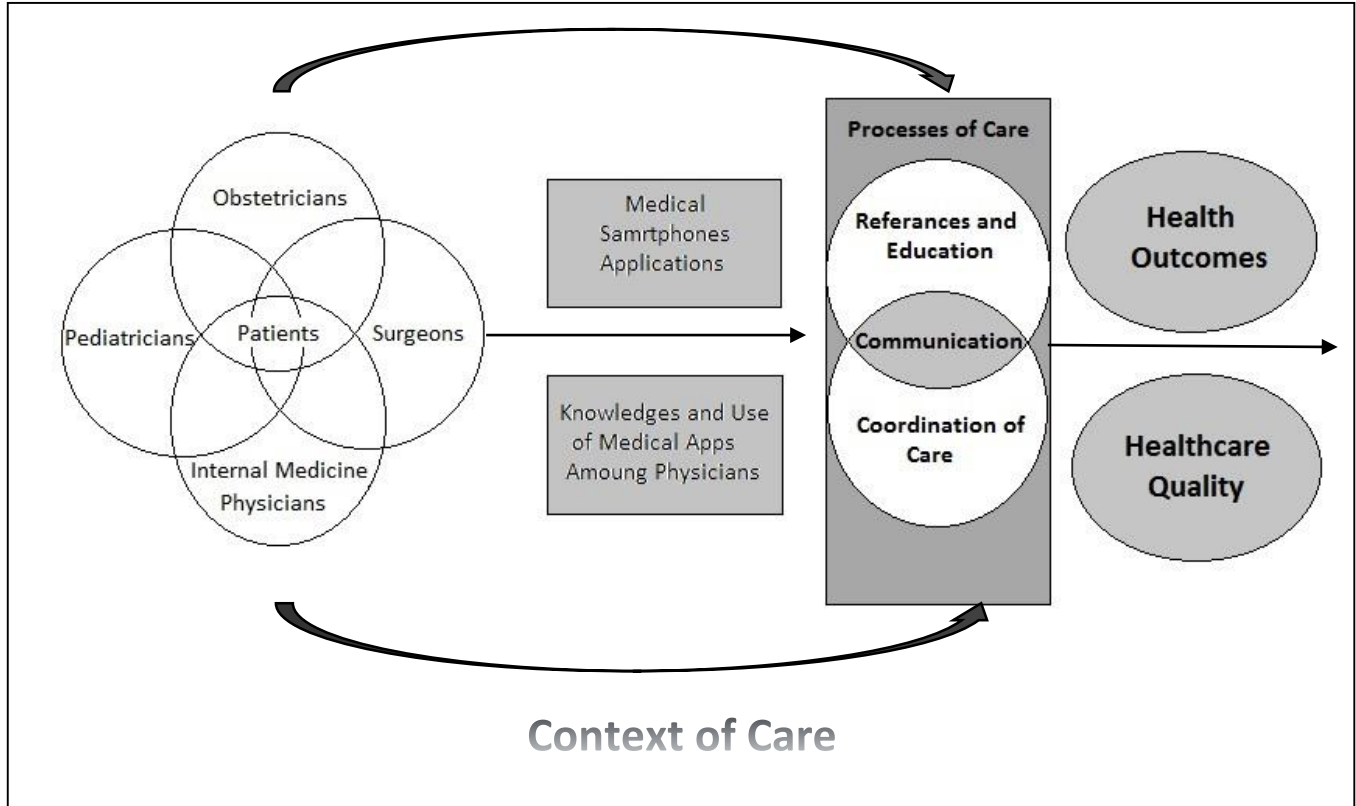


Figure 1: The Research Framework (Modified from: Hogan et al., 2014).<sup>29</sup>

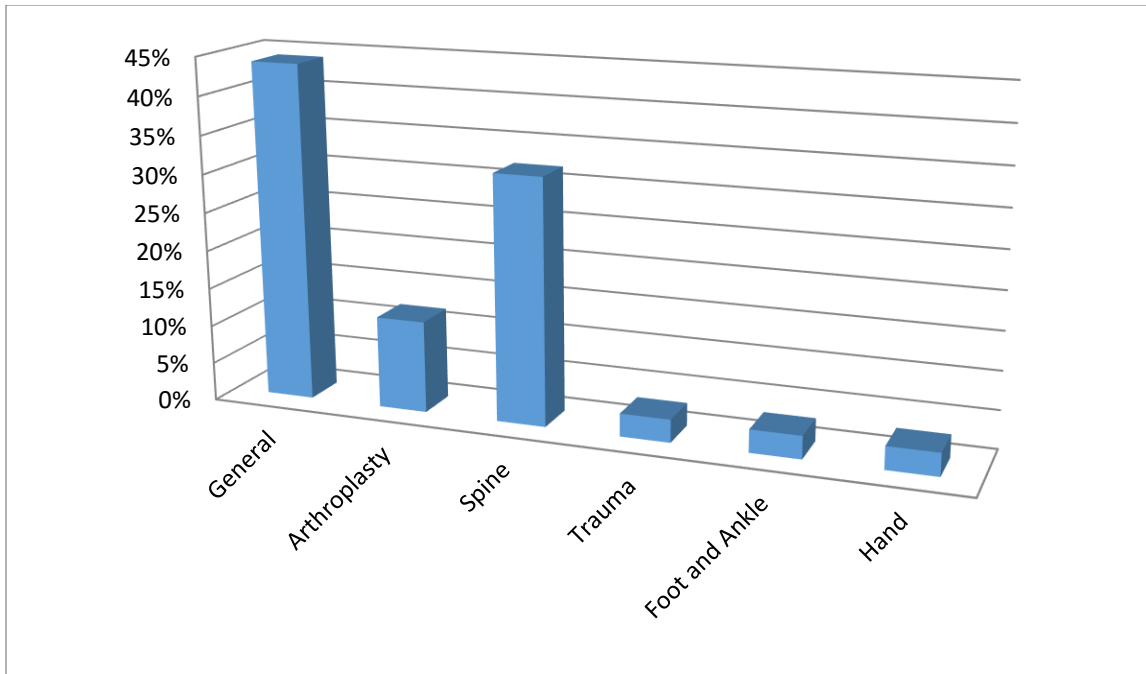


Figure 2: The distribution of apps designed for orthopedic providers by intended specialty (Franko and Bhola, 2011).<sup>38</sup>

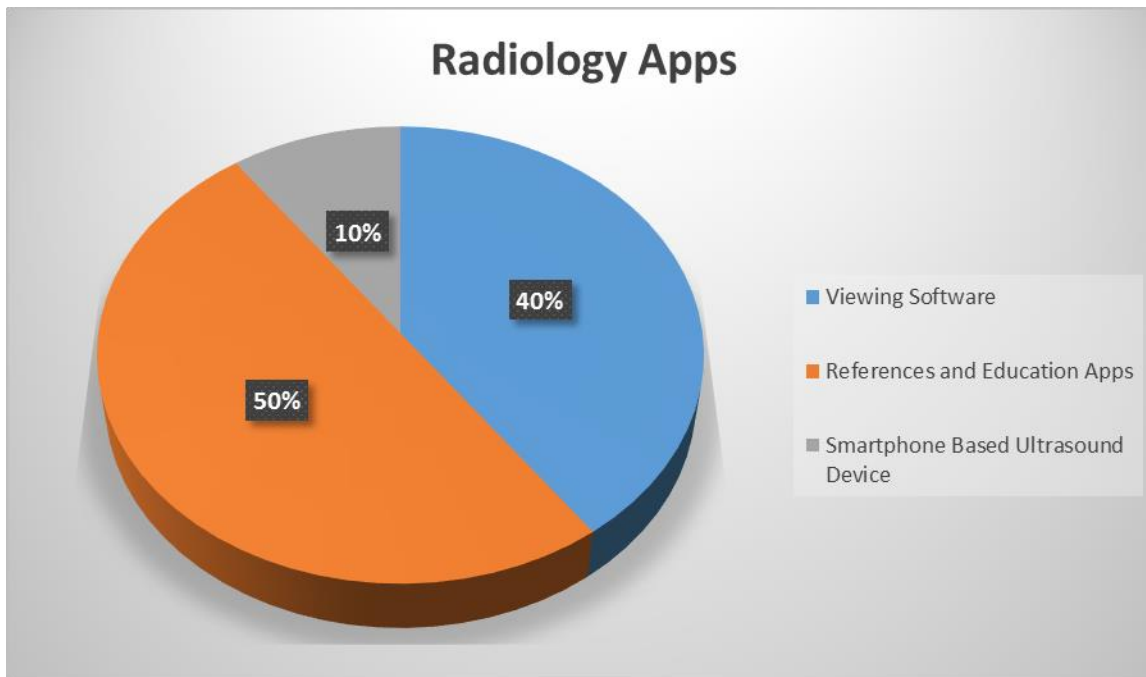


Figure 3: The percentage of radiology apps for several categories (Al-Hasani et al., 2013).<sup>43</sup>



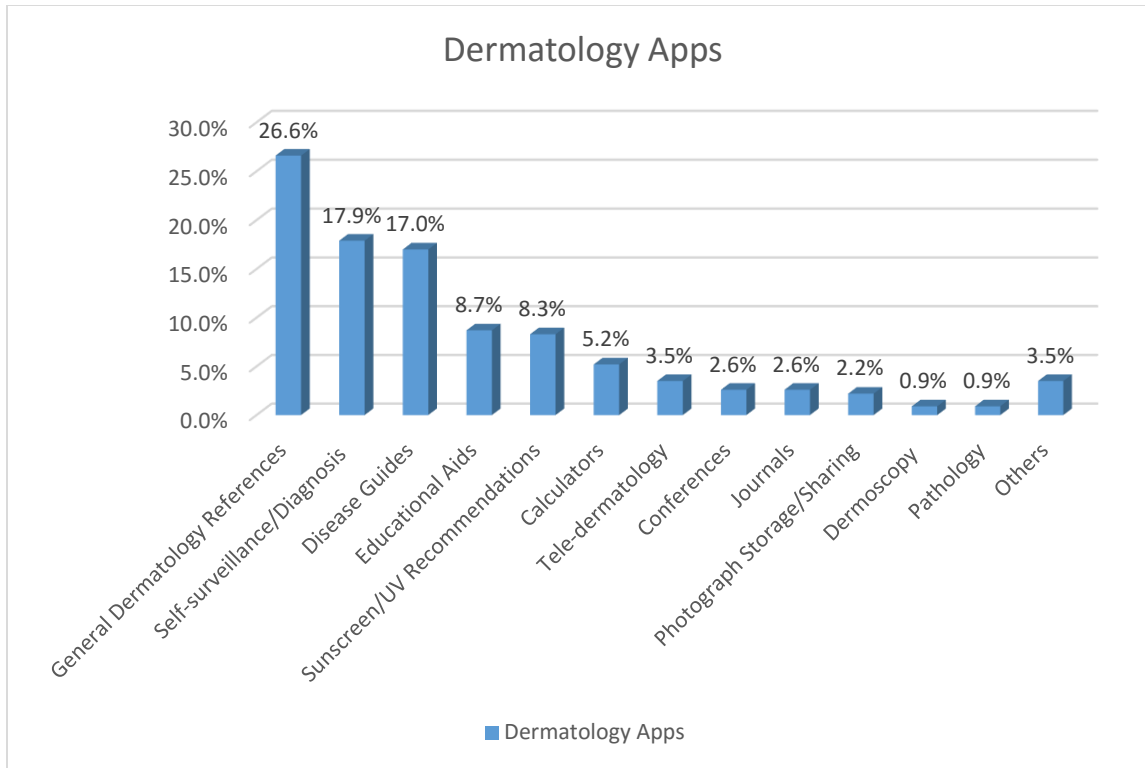


Figure 4: The percentage of radiology apps for several categories (Brewer et al., 2013).<sup>44</sup>

Table 1: Smartphone Apps Relevant to Pediatrics and Childcare (Sondhi and Devgan, 2013).<sup>34</sup>

Category	Number of Apps	Apps' Name
Reference and Education	27	<b>Pediatrics Central, Essentials of Pediatric Radiology</b> , Medscape, Skyscape, UpToDate, Journal RSS, PubMed on Tap Lite, , ICD 9 consult, Redi reader, Atlas of Congenital Heart diseases, Asthma, Blausen Human Atlas Lite, Johns Hopkins Abx guide, Journal with apps, Heart murmur pro, ECG guide, iResus, ICD 10, ACLS Rhythm, PFT Eval, Autism ihelp-Play, Pediatric airway, CoagGuide, Podcasts, SoundBuilder, Breastfeed, NeoTube
Calculators	8	<b>Phototherapy calculator</b> , MedCalc, Qx calculate, PICU calculator, , Children's Coma scale, Stat Growth Charts, BMI calculator app, ABG
Drug Information	5	Epocrates Rx, Micromedex drug information, Lexi Drugs, Sanford guide to antimicrobial therapy, MIMS
Epidemiology	2	iScrub Lite, Learn Stats
News	1	MedPage

Source: Sondhi, V., & Devgan, A. (2013).<sup>34</sup> Translating technology into patient care: Smartphone applications in pediatric health care. *Medical Journal Armed Forces India*, 69(2), 156-161.

Table 2: Smartphone Applications for Pediatric Anesthesia (Bhansali and Armstrong, 2012).

Smartphone Application	Developer	Description
<b>Peds anesthesia</b>	Innovate LCC	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• Functions include Endotracheal (ET) tube sizing tool, IntraOp crystalloid calculator, PreOp sedation, Age appropriate vitals, and IntraOp Medications</li> </ul>
<b>Paeds ED</b>	iED Limited	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• estimates weight based on age then derive the correct doses of drugs and equipment such as ET tube size</li> </ul>
<b>Drug calc</b>	Matthew Morgan	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• This takes the user, via an age selection button, to basic resuscitation information (epinephrine and atropine doses, ET tube size, fluid bolus, and DC shock).</li> </ul>
<b>Paediatric emergency drugs</b>	UBQO Limited	<ul style="list-style-type: none"> <li>• iPad size only</li> <li>• This app, using formulas developed in conjunction with the South Thames Retrieval Service and the Evelina Children's Hospital to provide clinical information for commonly used drugs, additional drugs and information, and appropriate sizes of anesthetic equipment based on age and weight.</li> </ul>
<b>Pedi safe</b>	iAnesthesia LLC	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• Features include weight based doses, weight estimator, airway equipment selection and size, normal vital signs for pediatrics, ACLS and PALS emergency medications, and simplify the medication delivery system</li> </ul>

<b>AnaPaed</b>	Thierry Girard	<ul style="list-style-type: none"> <li>• iPad size only</li> <li>• The main sections provide information standard medications, tubes and laryngeal mask airway, regional, antibiotics, analgesia, antiemetic, catheters and drains, blood loss, and all drug. The emergency section contains resuscitation information in six age-defined sections and calculate weight from age</li> </ul>
<b>Pediatric</b>	James Pearson	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• Provides information about airway, IV fluid, and vital sign data in a box at the top, with a full alphabetical list of all drug, airway, fluid, and resuscitation data</li> </ul>
<b>Peds Meds</b>	David Kammer	<ul style="list-style-type: none"> <li>• iPhone size only</li> <li>• Delivers information about pediatrics medication and calculations includes vital signs, fluid management, and tubes and lines sizing</li> </ul>
<b>PICU calculator</b>	ITDCS Ltd	<ul style="list-style-type: none"> <li>• iPad size only</li> <li>• Pediatric Intensive Care Unit (PICU) presents information includes physiology, airway, fluids, induction agents, muscle relaxants, resuscitation, infusions, and antibiotics</li> </ul>
<b>Drug doses</b>	Oliver Karam	<ul style="list-style-type: none"> <li>• iPad size only</li> <li>• No patient data is required to use it. It provides information in durgs, code blue, PedCalc (28 commonly used scores and formula), laboratories, and cardiology</li> </ul>

Source: Bhansali, R., & Armstrong, J. (2012).<sup>35</sup> Smartphone applications for pediatric anesthesia. *Pediatric Anesthesia*, 22(4), 400-404.