Creation of an iOS and Android Mobile Application for Inferior Vena Cava (IVC) Filters: A Powerful Tool to Optimize Care of Patients with IVC Filters

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Abstract

Owing to a myriad of inferior vena cava (IVC) filter types and their potential complications, rapid and correct identification may be challenging when encountered on routine imaging. The authors aimed to develop an interactive mobile application that allows recognition of all IVC filters and related complications, to optimize the care of patients with indwelling IVC filters. The FDA Premarket Notification Database was queried from 1980 to 2014 to identify all IVC filter types in the United States. An electronic search was then performed on MEDLINE and the FDA MAUDE database to identify all reported complications associated with each device. High-resolution photos were taken of each filter type and corresponding computed tomographic and fluoroscopic images were obtained from an institutional review board–approved IVC filter registry. A wireframe and storyboard were created, and software was developed using HTML5/CSS compliant code. The software was deployed using PhoneGap (Adobe, San Jose, CA), and the prototype was tested and refined. Twenty-three IVC filter types were identified for inclusion. Safety data from FDA MAUDE and 72 relevant peer-reviewed studies were acquired, and complication rates for each filter type were highlighted in the application. Digital photos, fluoroscopic images, and CT DICOM files were seamlessly incorporated. All data were succinctly organized electronically, and the software was successfully deployed into Android (Google, Mountain View, CA) and iOS (Apple, Cupertino, CA) platforms. A powerful electronic mobile application was successfully created to allow rapid identification of all IVC filter types and related complications. This application may be used to optimize the care of patients with IVC filters.

Keywords

- mobile application
- electronic tool
- interventional radiology

Objectives: Upon completion of this article, the reader will be able to discuss how mobile applications are impacting today's health-care system and how they can be used to improve the care of patients with indwelling IVC filters.

Accreditation: This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of Tufts University School of Medicine (TUSM) and Thieme Medical Publishers, New York. TUSM is accredited by the ACCME to provide continuing medical education for physicians.

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A mobile application (app) is a computer program designed to run on electronic mobile devices such as smartphones and tablet computers. Mobile apps were originally developed for the general public to help boost productivity and information retrieval, but apps are now specifically

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Fig. 1 Sample of initial wireframe for mobile app.

designed for a variety of fields including medicine. Apps may now assist health-care providers with a multitude of tasks including clinical references, medical calculations, and even clinical decision making. The authors aimed to apply mobile app technology to help clinicians caring for patients with indwelling inferior vena cava (IVC) filters.

In the United States, the use of IVC filters has steadily increased over the past 30 years,¹ and more than 250,000 filters are now placed annually in the United States resulting in an epidemic of filter-related complications.² Currently, the myriad of IVC filter types encountered in clinical practice, the clinical implications from prolonged implantation, and the potential for device-specific complications remain a source of confusion among clinicians. Indeed, despite the wide availability and use of cross-sectional imaging, rapid and correct identification of IVC filter types may be challenging due to the myriad of IVC filter types. The authors aimed to develop an interactive mobile app that allows recognition of all IVC filters and electronically organizes key clinical and safety data for each filter type, to provide a useful clinical tool for physicians caring for IVC filter patients.

Materials and Methods

The Food and Drug Administration (FDA) device approvals, denials, and clearances database was queried electronically

for IVC filters receiving premarket (510K) approval (product code DTK—filter, intravascular, cardiovascular).³ From a pristine filter collection, high-resolution photos were taken of each filter type. A searchable institutional review board–approved IVC filter registry (NCT01158482) was used to collect representative computed tomographic (CT) and fluoroscopic images for each device. Next, an evidence-based electronic search (MEDLINE, FDA MAUDE database) was performed to identify the key clinical and safety data for each filter type including the following: device-specific complications, optimal retrieval window, treatment options for removal, and technical specifications.⁴ A wireframe (►Fig. 1) and storyboard (►Fig. 2) were created, and the software was developed using HTML5/CSS compliant code and Coda2 (Panic, Portland, OR) environment. The software was then deployed using PhoneGap (Adobe), and the app prototype was tested, refined, and finalized for public launch.

Results

Twenty-four IVC filter types were identified, and 23 types were included. The Edwards Mobin-Uddin device was excluded, as it was removed from the market in 1986.⁵ Among FDA-approved devices, 9 were approved for permanent use and 14 were approved as retrievable and permanent devices (►Table 1). The following device specifications were recorded: shape, material, delivery size, maximum IVC diameter, and magnetic resonance imaging (MRI) compatibility. The following complication rates were obtained: fracture, insertional issues, migration, perforation, recurrent venous thromboembolism, and IVC occlusion. A mobile app was constructed, using the HTML5 standard, to organize the digital photographic, radiographic, and clinical data in a format that allows easy search and instant access (►Fig. 3). The main menu of the application (►Fig. 4) was organized into submenus for general information about IVC filters (“General”), device-specific information sheets organized alphabetically by device name (“IVC filters”), an image gallery for visual identification of IVC filters (“by Image”), literature references (“References”), and information about the application (“About”).

General clinical information (►Fig. 5) was provided including the following: the 2010 and 2014 FDA safety communications regarding retrievable IVC filters^{2,6,7}; indications for IVC filter placement based on guidelines from the Society of Interventional Radiology (SIR), American College of Chest Physicians (ACCP), American Heart Association (AHA), and Eastern Association for the Surgery of Trauma (EAST) guidelines^{8–11}; and radiographic examples of each type of filter complication.

Devices were organized alphabetically by name in the “IVC filters” section (►Fig. 6) and linked to information pages for each of the 23 FDA-approved IVC filters. For each device page, safety considerations for each filter type, information on the optimal retrieval window, options for IVC filter removal, and representative imaging were included (►Fig. 7). Additional specifications were placed in the “Technical Specifications” section including the FDA approval date, material, insertion routes, sheath size, maximum IVC diameter, and MRI compatibility. Representative imaging results including digital

Fig. 2 Storyboard used in mobile app development.

photos and radiographs, to aid in device identification, were placed immediately beneath the "Technical Specifications" section (►Fig. 8). Fluoroscopic and interactive CT imaging studies were made available on the app (►Fig. 9). An integrated PACs system was included to allow the user to scroll through representative CT images for each device. In addition, an image gallery containing all 23 FDA-approved devices was made accessible from the main menu (►Fig. 10). Finally, each image from the gallery was linked to the corresponding device page for rapid access.

Discussion

Smartphones, personal digital assistants, and tablet computers have become ubiquitous in modern society. Apps are now available to assist health-care providers with various tasks including health record maintenance and access, communications, consulting, information gathering, patient management and monitoring, clinical decision making, and medical education.¹² The availability of mobile devices and mobile apps has shifted the medical paradigm and given health-care providers and patients rapid access to vast amounts of information at the point of care.¹² Previous studies have demonstrated that access to these point of care decision-making tools can improve clinical decisions

and patient outcomes.¹³ Therefore, the use of mobile apps in the health-care setting can provide convenience, better clinical decision making, improved accuracy, increased efficiency, and enhanced productivity.¹²

Given these potential benefits, the authors aimed to develop a mobile app to help physicians who may encounter patients with potential risks or complications from indwelling IVC filters. In the United States, rising filter use has resulted in an epidemic of filter-related complications. These risks led the FDA to issue a safety alert in August 2010 recommending the removal of retrievable IVC filters as soon as protection from pulmonary embolism (PE) is no longer needed² to prevent filter-related complications. In 2014, the FDA released another safety communication stating that the risk-to-benefit ratio begins to favor IVC filter removal within 29 to 54 days after implantation if the risk for PE has passed.^{6,7} Despite these warnings, an increasing number of filters and filter types are being implanted annually resulting in confusion when encountered by clinicians.

As described here, mobile IVC filter app was successfully developed allowing clinicians to identify any filter currently encountered in the United States. Once identified, the application provides a quick reference of clinically relevant data. For instance, if a Bard Recovery filter (Bard Recovery, Tempe, AZ) is identified, the clinician can quickly learn that the device

Table 1 FDA-approved IVC filters from 1980 to 2014

Device	Company	FDA approved	Retrievability
ALN	ALN International, Miami, FL	2008	Permanent
Recovery	Bard Peripheral Vascular, Tempe, AZ	2003–2005	Retrievable
G2	Bard Peripheral Vascular	2005–2008	Retrievable
G2X	Bard Peripheral Vascular	2008	Retrievable
Eclipse	Bard Peripheral Vascular	2008	Retrievable
Meridian	Bard Peripheral Vascular	2011	Retrievable
Denali	Bard Peripheral Vascular	2013	Retrievable
Simon Nitinol	Bard Peripheral Vascular	1990	Permanent
LGM/Vena Tech LGM	B. Braun Medical, Bethlehem, PA	1989	Permanent
Vena Tech LP	B. Braun Medical	2001	Permanent
24Fr SS Greenfield	Boston Scientific, Natick, MA	1973	Permanent
12Fr SS Greenfield	Boston Scientific	1995	Permanent
Titanium Greenfield	Boston Scientific	1989	Permanent
Günther Tulip	Cook, Bloomington, IN	2000/03	Retrievable
Celect	Cook	2007/08	Retrievable
Celect Platinum	Cook	2012	Retrievable
Bird's Nest	Cook	1989	Permanent
Optease	Cordis Endovascular, Warren, NJ	2002/04	Retrievable
Trapease	Cordis Endovascular	2000	Permanent
Option	Argon Medical Devices, Plano, TX	2009	Retrievable
Option Elite	Argon Medical Devices	2014	Retrievable
Crux	Volcano, San Diego, CA	2012	Retrievable
SafeFlo	Rafael Medical Technologies, Dover, DE	2009	Permanent

Abbreviations: FDA, Food and Drug Administration; IVC, inferior vena cava.

Fig. 3 Screenshot of the main page of the mobile application entitled "IVC Filter Compendium." **Fig. 4** Screenshot of the main drop-down menu.

Fig. 5 Screenshot of the general information menu.

Fig. 6 Screenshot of the IVC filters menu. Additional devices may be reviewed by scrolling down the menu.

was originally FDA approved in 2003 but discontinued in 2005 due to complications (such as fracture rates up to 25%).¹⁴⁻¹⁷ This knowledge may lead the clinician and/or radiologist to search for fractured and embolized filter com-

ponents more closely on radiographic studies, which may lead to recommendations for treatment with prompt filter removal. Similarly, if a Cook Select filter (Cook Select, Bloomington, IN) is identified in a patient presenting with

Fig. 7 Screenshots of the information page for the Cook Select filter.

Fig. 8 Screenshot showing the imaging available for each device. A high-resolution photograph is immediately available to the user. The fluoroscopic and scrollable CT images are available by hyperlink (below photo).

Fig. 9 Screenshot of a scrollable CT showing the Select filter appearance on cross-sectional imaging.

Fig. 10 Screenshot of the image gallery showing the Bard Recovery retrievable IVC filter.

abdominal pain, the physician can learn that this filter type is associated with penetration rates of up to 93%,¹⁸ and should pay close attention to identify filter penetration as a potential etiology for pain.

In summary, a powerful electronic mobile app was successfully created to allow rapid identification of many IVC filter types and to raise awareness of their potential device-specific complications. The application may serve as an educational tool for medical trainees, clinicians, and patients who wish to learn more about IVC filters, as well as a clinical tool to help optimize the care of patients with IVC filters.

Note

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