

# Smart Medication: Electronic Diary, Medication Management and Analysis Tool of Haemophilia Home Treatment: Development, Implementation, Test and Operating of a Telemedicine Platform

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## ABSTRACT

Ubiquitous computing based on high speed internet and mobile devices facilitate dramatically new possibilities in the health care sector. Patients with rare chronic diseases, often living far away from the medical center, benefit from telemedicine and telemonitoring in particular. We describe how a telemonitoring platform called “smart medication” developed by medical and IT experts can improve the care of patients with the rare chronic disease haemophilia. The study reports the experience of developing, implementing, testing and operating the platform in Germany, Austria and Switzerland. We point out functional and non-functional requirements as well as barriers of mobile application development used for the health care sector. Our findings emphasize that patients adapt to telemonitoring systems quickly, that the use of adequate technology reduces health care costs and increases the life-quality of patients substantially.

**Keywords:** *Telemedicine, telemonitoring, healthcare information systems, IS use, mobile devices, mobile application development, home treatment, haemophilia*

## 1. INTRODUCTION

Telemedicine can be found in health care for more than 100 years. The use of telegraphy, telephone, radio and television for transmission of medical data such as X-ray photographs started in the late 19th century. Initially to bridge the distance between the doctor and the patient the targets were mainly seamen and air crews [1; 2]. During the 20th century the use of telecommunication systems in the health care sector increased with the improvement and development of new technologies and networks. A definition of telemedicine was given by the WHO in 1998:

Telemedicine is “the delivery of health care services, where distance is a critical factor, by health care professionals using information and communications technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interest of advancing the health of individuals and their communities” [3].

This means that not every use of technology for a medical reason can be called telemedicine. The use of information and communication technologies (ICTs) has to be for sharing medical information over a critical distance and has to affect the quality of patient care.

The internet as a transmission medium, new standards and new technologies allow and provide a new and dramatic raise of quality in patient care. The specialist care can be delivered everywhere at any time. Especially for rare and chronic diseases such as haemophilia, when the long distance between the patient’s home and the next medical expert prevents a short consultation, only the use of (ICT) tools can provide high quality and the continuity of care. Mobile devices such as

smartphones and tablets can be used for therapy monitoring, recording patient data and with connected sensors even for measuring vital signs such as pulse, blood pressure, blood sugar or rate of breathing. The recorded data can be sent, analyzed, prepared and presented without any loss of time to the doctor. With the data the therapy can be adjusted, particular events can be filtered and certain variations identified at the time of occurrence.

The fact that more than 50 % of the population in Europe already owns a smartphone illustrates the potential for the telemedicine sector [4]. However, there are not just advantages, but also a lot of challenges to manage, e.g. data security and safety need to be guaranteed; the equipment acquisition, training and education for the users can be cost-intensive; adequate internet connection or access to necessary hardware does not exist everywhere; the patient-doctor-relationship can become corrupted; a lack of useful functionality, because neither the doctor nor the patient was involved during development; no funding for the time after the pilot phase to move into production and to run the system; to name just a few [5].

This paper describes the development, implementation, test and operating of a telemedicine platform at first in Germany and later in Austria and Switzerland. Built for patients with haemophilia the current situation of the treatment will be illustrated and why especially a rare and chronic disease can benefit from the use of modern technology. The new but implemented and growing system smart medication will be described. The aim of this paper is to illustrate benefits and barriers for a telemedicine platform not just theoretically but also using the example of a running system. Earlier reports on work in progress have been published and form the basis for this paper [1; 6; 7; 8; 9].



## 2. HAEMOPHILIA

### 2.1. Fundamentals of the chronic disease

Haemophilia is a rare x-chromosomal inherited bleeding disorder. Haemophilia A and B are characterized by reduced or absence of the coagulation factor VIII or IX, respectively [10]. Haemophilia A has a prevalence of 1 in 10,000 and haemophilia B of 1 in 50,000 males worldwide [11; 12]. The missing coagulation factor may lead to repeated bleeding episodes in all major joints and muscles with the consequence of severe arthrosis and finally disability. Massive bleeding and cerebral bleeding are usually life threatening [13]. The missing coagulation factor needs to be administered intravenously on a regular basis (prophylactic treatment) or in case of suspected or overt bleeding (on-demand). Since the availability of factor concentrates in the early 1970s the life expectancy increased from less than 20 years to almost normal. Also, quality of life improved dramatically with hardly any joint damage or life threatening bleeding. Prophylactic treatment especially beginning in early childhood has developed as regimen of choice [8; 14; 15].

Unfortunately, in the late 1970s and early 1980s most concentrates manufactured from pooled plasma obtained from thousands of donors were contaminated with blood-borne viruses such as hepatitis B, hepatitis C (HCV) and the human immunodeficiency virus (HIV). Almost all patients were infected by HCV and a high percentage also by HIV [10]. Until the mid-1990s approximately half of all patients infected by HIV died and an increasing number of liver failures due to HCV is still registered [16]. This was a dramatic drawback in haemophilia care. New standards in purification procedures of plasma derived concentrates and the development of recombinant products improved the safety concentrates, so that the issue of infection was solved since the mid-1980s [14].

Because of the contamination of the factor concentrates in the past and thus according to German law (Transfusion Act) every treatment with plasma derived and also recombinant blood needs to be thoroughly documented. This includes cumulative data (batch number, quantity and type of the product) as well as the possibility to track the administered dose to the respective patient (German Federal Ministry of Justice) [17]. The usual way of recording treatment data by the patient is to fill in all data into a traditional paper diary. This way of documentation causes many problems. Mistakes in writing, unreadable handwriting, loss of diaries and with it the loss of all the treatment data, a long time gap between the documentation and the possibility of analyzing by the haemophilia treatment center are just some of the issues [18; 19].

### 2.2. Current situation in and barriers for surveillance of haemophilia home treatment

The patient gets his coagulation factor from the haemophilia treatment center or from the pharmacy, treats himself intravenously at home without any surveillance of his doctor, fills the treatment information into a paper diary and goes for consultation mostly twice per year. The paper records with hundreds of entries need to be manually entered before the treatment data can be analyzed, which is an unacceptable and almost infeasible work for a haemophilia treatment center [19; 20]. The 10 to 12 data points such as the personal data plus the treatment information from a patient who treats himself 3 times per week over 6 months (26 weeks), extrapolates to a minimum of 780 to 936 data points. Therefore a haemophilia treatment center with one hundred patients would have to manually enter over 150,000 data points per year. This is almost impossible to accomplish by the haemophilia center and an optimization of the therapy on the basis of the patients' treatment data is very limited because of the already named problems. Furthermore, the requirements of the German/EU law (German Transfusion Act (Transfusionsgesetz - TFG)) can be hardly fulfilled, if the doctor has access to the treatment data only twice a year.

### 2.3. Former telemedicine platforms

During the last 20 years several telemedicine platforms were developed to replace the paper diary with an electronic documentation system. But systems such as "Advoy" of the pharmaceutical company Baxter, "Haemonet" of Novo Nordisk and "Dialog" of Bayer are hardly in use or failed in Germany for several reasons e. g. [21]: Some systems were developed by just one company and therefore product-bound; the platforms were used only for advertising purposes; neither the doctor nor the patient were involved in the development and the systems hardly fulfilled their needs or were just too complicated to use; no adaption of the system to new technology; requirements named by medical experts or patients were not considered; the use of a device restricted to the application (App) and the need of the user to carry a second device beside his private mobile phone. These reasons are just some examples why the common way of treatment documentation in Germany and most other countries is still per paper diary.

## 3. SMART MEDICATION – A MULTI-PLATFORM DOCUMENTATION AND MONITORING SYSTEM

### 3.1. Requirements to the system

The possibility of self-treatment at home provides a high quality of life with an improved life expectancy to a patient with severe haemophilia. Concerned persons are hardly restricted in their daily private and working life and the necessity of consultation is reduced dramatically. Today patients live up to 200 km away from the next haemophilia



treatment center and visit it approximately twice per year [22]. But this implies a structured and continuous monitoring by the haemophilia treatment center. The usual paper diaries and sporadic consultation make this almost impossible. Besides, the requirements of the Transfusion Act such as immediateness of data recording, data transmission in the case of side effects, quality management and retraceability of the concentrates cannot be entirely fulfilled. In particular the contamination of the factor concentrates with blood-borne viruses in the late 1970s illustrated the necessity of immediate backtracking of every batch [16; 18; 20]. To achieve an optimal surveillance by the haemophilia treatment center and to provide all data required by law, at least the following information needs to be recorded:

- Identification number of the patient, full name, date of birth, and address;
- Batch and pharmaceutical registration number;
- Date and time of the injection;
- Treatment reason;
- Time gap between the bleeding and the injection;
- Bleeding locations;
- Amount of used factor concentrates;
- Weight of the patient.

### 3.2. The Electronic Diary

The use of telemedicine and telemonitoring provides a solution. The problems of monitoring the patient, his treatment and bleeding data, and with it the possibility of therapy optimization over every distance, as well as providing all requirements of the law can be solved by using mobile technologies [23; 24]. The possibility of immediate transmission, examination and supply of data provides a new quality of surveillance of haemophilia home treatment. Previous studies showed that most patients are willing to use electronic handhelds for documentation and also many advantages which result from the availability of the treatment data in an electronic form [19; 20].

### 3.3. The System Smart Medication

Former implementations of electronic diaries could not fulfill the requirements of the haemophilia treatment centers, patients and the Transfusion Act. They were used only for advertizing, often developed by pharmaceutical companies and therefore product-bound or used antiquated technologies. Therefore in 2011 a new system named smart medication was developed as a scientific project in collaboration between the Philipps-University in Marburg, medical experts on haemophilia treatment in Frankfurt and Münster, the IT Company Rösch & Associates Information Engineering GmbH and the society for

advancement of telemedicine in the haemostaseology (Verein zur Förderung der Telemedizin in der Hämostaseologie – VFTH e.V.) [7; 8]. The aim of the project was to develop a system which is independent of any pharmaceutical company, free to use factor concentrates of all vendors and uses state of the art technology.

### 3.4. Technology Used

In choosing an operating system (OS) as a basis for a mobile application some issues need to be considered. The aim is to provide an application which can be used by most patients using their own devices. Choosing the wrong technology can lead to a failure of the whole project. Further projects showed that most patients do not want to use a second device but rather their own. At the same time it is almost impossible to support all operating systems with a native app, because of the huge requirements on human resources and assets. The development of a complex mobile application such as a telemedicine app has fixed costs of at least € 200,000. Costs thereby incurred e. g. during the following steps:

- Planning of the application and the backend as well as its specifications in collaboration with physicians and patients has to be done before development can start. A draft and screenshots have to be designed and again discussed with the future users. This takes around 2-3 months.
- Hardware such as mobile devices, computer, server and software licenses for the development and the future operation need to be bought and installed.
- The development of the defined applications, with all the declared functionalities, the required access protection, icons and needed images takes about another 3 months.
- Close to the end of the development the test phase has to start and takes around 2 months. The functionality, security and safety issues, usability and performance, data collection, conversion, transfer and allocation have to be tested and bugs have to be fixed. Especially data security has very high requirements relating to the use of patient data.

Considering that the data has to be stored on a central server with all the required security issues, the application has to be enhanced and adapted to changes and new technologies, the patients and the physicians have to be trained and need to be supported, licenses have to be provided and renewed, there are follow-up and recurring costs which are not included in the fixed costs.

Therefore, the decision of supporting one operating system cannot be taken without including the market trends. During the last 5 years e. g. the leading operating system called

<sup>1</sup> <http://www.vfth.org>



“Symbian” with a market share of almost 50% in 2009 is no longer supported since 2012 and “Android” by Google grew from less than 4 % to almost 50 % at the end of 2012. But also other operating systems lost or won more than 50 % of their former market share. Table 1 and figure 1 illustrates the development of the market from 2009 To 2012 [1; 25; 26].

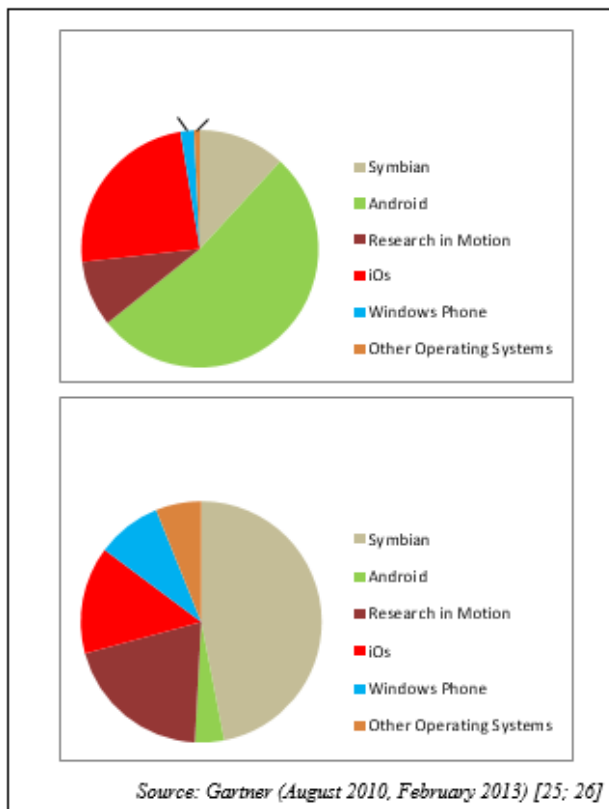
**Table 1. Forecast: Mobile Communications Device Open OS Sales to end users by OS (thousands of units)**

OS	2009	2012
<b>Symbian</b>	80,876.3	17,458.4
Market Share (%)	<b>46.9</b>	<b>11.6</b>
<b>Android</b>	6,798.4	77,054.2
Market Share (%)	<b>3.9</b>	<b>51.3</b>
Research In Motion	34,346.8	13,184.5
Market Share (%)	19.9	8.8
iOS	24,889.8	35,456.0
Market Share (%)	14.4	23.6
Windows Phone	15,031.1	2,759.0
Market Share (%)	8.7	1.8
Other Operating Systems	10,431.9	1,166.5
Market Share (%)	6.1	0.8

Based on the expected market trends Android was chosen to build a prototype in 2011. The aim was to access as many patients as possible, but also have an aspiring operating system with potential to become market leader. Another advantage compared to the other vendors is the open source strategy of Google. Whereas iOS by Apple and Symbian by Nokia only run on the company’s own devices, the operating system Android is supported by different smartphone providers, which supports the spread of the OS. A reason to choose Android was also the easy and unrestricted possibilities to offer the applications to the end user. For example, Apple is following a closed shop strategy, which means that a user of apple products can only install software which comes from the iOS App Store. This means that Apple has the right to remove apps without any explanation and can keep updates from being published without any reason. In contrast, an Android application can be offered everywhere without any restrictions. A fourth reason is that smartphones with the operating system Android are offered in every price category from low cost to high end devices [1]. These are just some reasons why Google’s OS was chosen. However, after the test phase in 2012 we learned that one supported platform is not enough, even if it is the market leader with 50 % market share. We underestimated the problem that smartphone users normally do not want to change the vendor of their device, even if they can get a free new smartphone. Also the possibility of using a second device just for documentation did not convince the concerned patients. Therefore the strategy changed from developing a native application for one mobile operating system to a second web application based on HTML5 (Hypertext Markup Language).

HTML5 is still under construction and experts expect that the new technology will not be completed before 2022, but the current version is already in use and seen as a working almost finished technology [27]. Most of the implemented functionalities will not be changed again and are already supported by almost every web browser. The new standard HTML5 is supported e. g. by Google Chrome, Mozilla Firefox, Apple Safari, Opera and Microsoft Internet Explorer. These browsers can be used on all devices (smartphones, tablets, laptops and desktop computers), so that a web application is device independent. New features are offline functions, an integrated database, access to local hardware resources of the running device, drag and drop functions and so on. In spite of the unfinished technology global players such as Google, Amazon, Intel and Samsung are already using HTML5 for developing. Examples for web applications are YouTube and Vimeo Video Player, Amazon Kindle Cloud Reader, Google Gmail, Calendar and Docs, SlideShare and the operating system Tizen. Experts are convinced that HTML5 has great potential and are investing huge amounts of money in this technology.

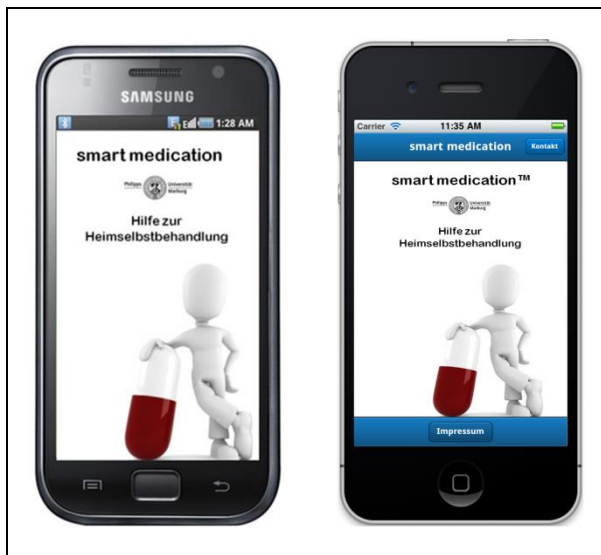
Besides the great advantage of device independency, a second reason of using HTML5 is the possibility of building an



**Fig.1. Forecast: Mobile communications device open OS sales to end users**

application using frameworks such as PhoneGap<sup>2</sup>, Appcelerator Titanium<sup>3</sup> or SenchaTouch<sup>4</sup>. These frameworks afford the look and feel of a native application to a normal web application [6].

We decided to use the framework Sencha Touch 2 for development. The problem of Sencha Touch is the use of the layout engine software called WebKit, which is still not supported by every web browser. Besides that, Sencha Touch is an all-in-one framework which offers many tools to build touch-based applications, to give a real native application look, to access local resources and to package it in a native shell. Figure 2 shows the application for treatment documentation on the two smartphones Samsung Galaxy S i9000 (native Android application) and iPhone 3 GS (HTML5 application built with Sencha Touch 2).

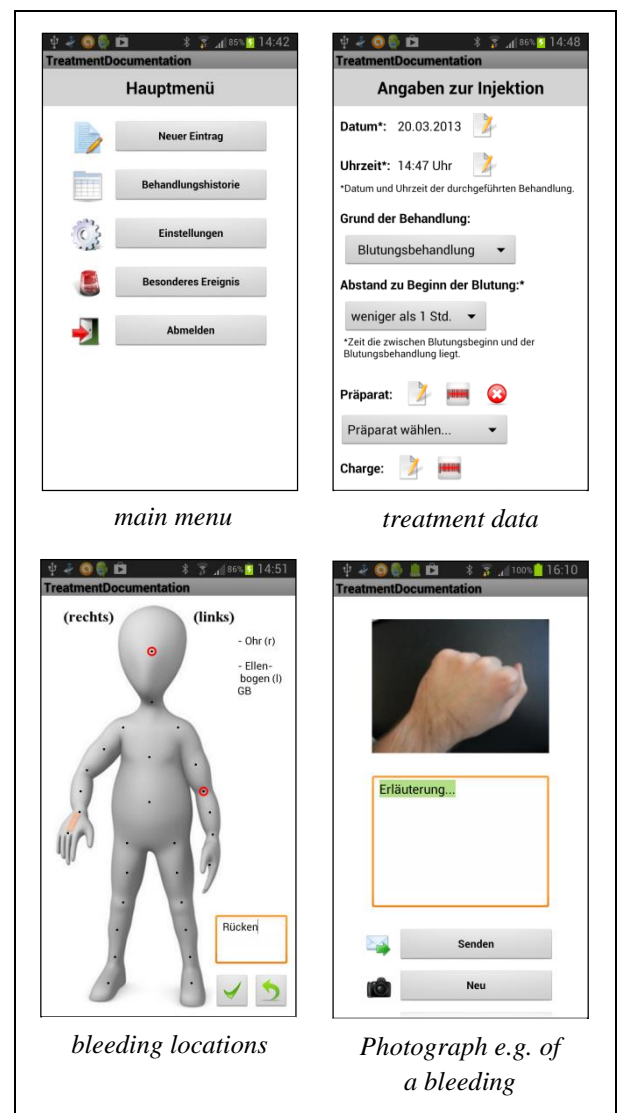


**Fig. 2. The electronic substitute diary on the 2 smartphones Samsung Galaxy S i9000 and iPhone 3 GS.**

### 3.5. The System and its Components

The system consists of three components: Firstly, an application for the patient as an electronic diary to record the treatment data such as the details of the injection (e.g. time, date, details and the amount of the concentrate used) and further information such as the reason (prophylaxis or on-demand) and the actual weight of the patient, if necessary the bleeding locations. The application also provides the possibility of contacting the doctor per call or text message, documenting if necessary the product stock of the given concentrates, reporting a hospitalization and photographing a bleeding to send it to the haemophilia treatment center with a text message. To avoid type errors the user has the possibility of choosing most of the requested information from lists

(figure 3). In addition the application checks if the date is not in the future, if the entered product exists and if all required data has been entered. After completion all recorded data will be transmitted immediately to a central server, analyzed, prepared in real time and allocated to the doctor without any delay. If the patient has no internet connection, the application saves the data locally and tries to send it again automatically without the need of the user to interact.



**Fig. 3. The electronic substitute diary "TreatmentDocumentation".**

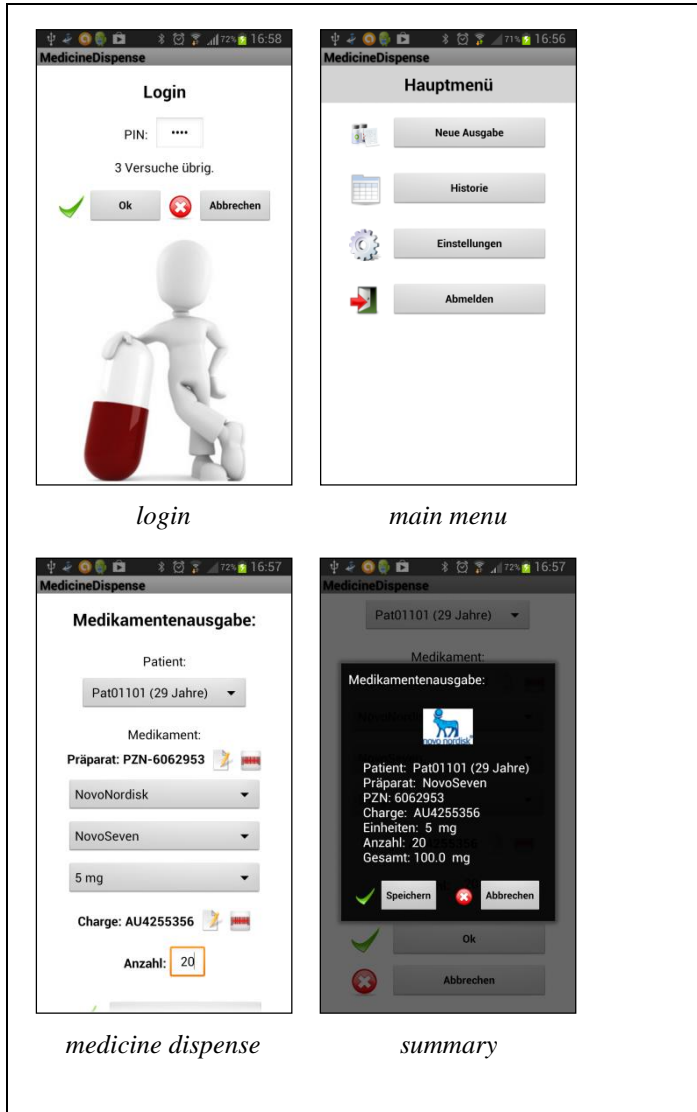
Secondly, an application for medication management and use by the haemophilia treatment center to document all dispenses of factor concentrates to patients, which affords a continuous

<sup>2</sup> <http://www.phonegap.com/>

<sup>3</sup> <http://www.appcelerator.com/>

<sup>4</sup> <http://www.sencha.com/>

stocktaking. Figure 4 shows the user interface of the application named “medicine dispense”. The physician can choose the relevant patient and the factor concentrate from lists, scan the barcode of the batch using the camera of the smartphone and enter the amount with the keyboard



**Fig. 4. Application for medication management called “MedicineDispense”.**

Thirdly, a real-time reporting system provided as a website. The home page first gives an overview of all the patients of the haemophilia center, their recorded treatment data, the number of entries, date of the last entry, the available product stock, number of all bleedings, bleedings in the last 3 months and in the last 7 days. A second page provides all details of a chosen patient. It can be compared with the paper diary, but bleedings are highlighted in red. In addition to the patient details the

doctor can select different analyses and graphs of the treatment and bleeding events. With these monitoring tools the doctor can identify e. g. out of stock situations, if the patient is following the treatment recommendations, particular events such as increased number of bleedings, and the development of so called “target joints” (joints with repeated bleeding and progressive arthrosis). If any abnormality arises, the doctor can immediately contact the patient for consultation and adjust the therapy. Changes of therapy can be monitored and a success or more important a failure can be identified early enough to prevent negative consequences for the patient. With a look in the common paper diary every 6 months the doctor can only adapt the therapy ex post and only if he can identify any abnormality.

### 3.6. Implemented Security Functions

Data security is an important issue in the handling of patient data. The smart medication system includes different safety functions. During the development the recommendations of the Federal Office for Information Security were consequently used [28]<sup>5</sup>. For example the following functionality has been implemented:

- **Pseudonymization of the patient data:** Exclusive use of ID’s instead of names and other details, which could identify a patient. Only the doctor knows the connection between an ID and the patient, because no personal data like name or address is stored in the data base.
- **Server operation in a high-security computer center:** The server of the smart medication platform is set up in a high-security computer center of the company COLT Telecom in Frankfurt and uses the generally used safety functions of banks and insurance companies for IT-security such as access control, climatization, fire protection, etc. The computer center is certified to DIN/ISO 27001.
- **Daily backup:** The backup of the databases is done every day. The data of the backup is encrypted, transferred to a safety server and thus not usable for a third party.
- **Access protection per PIN/PUK procedure:** To use the application the patient has to know his user-ID and his personal identification number (PIN). If he uses a wrong number 3 times in a row he has to use his personal unblocking key (PUK). After another 3 wrong inputs, the application will be blocked until the support unlocks it remotely. This technique corresponds to the accredited security technique of the subscriber identity module (SIM) for smartphones.

<sup>5</sup> [https://www.bsi.bund.de/EN/Publications/TechnicalGuidelines/TechnicalGuidelines\\_node.html](https://www.bsi.bund.de/EN/Publications/TechnicalGuidelines/TechnicalGuidelines_node.html)

- **Client-server-communication per TLS/SSL-protocol:** The transmission of all data is encoded per TLS/SSL protocol. The used key length amounts 2048 bit and correlates with the encryption used for online banking.
- **Password encryption:** All passwords in the database are encrypted with the hash-function (SHA-512). This makes it impossible to reconstruct the login data of the user.
- **Audit trail of the database:** Every change (new datasets, change or deletion of data) in the database done by the doctor, patient or support is documented with date, time and initiator.
- **Check of data input:** During manual input of treatment data the application executes a plausibility check. For example, only the pharmaceutical number of an existing factor concentrate can be entered.
- **Data management on the local device:** The history of treatment data saved on the mobile device will be deleted after 90 days. With a loss of the device and password of the application a third party can only see the treatment data of the last 3 months [8].

These are just some of the implemented security functions.

## 4. TEST AND OPERATION OF THE TELEMEDICINE PLATFORM

### 4.1. A Six Month Test Period

In the beginning of 2012 four haemophilia treatment centers from different German cities and 29 patients with haemophilia who were participating in a home care infusion program and using factor concentrates on a regular basis were chosen for a 6 months live test of smart medication. Recruited patients were to use both the electronic diary and a traditional paper diary to record treatment data. The haemophilia treatment centers were instructed to document every medicine dispense to the patient. There were no limitations for the haemophilia treatment centers in choosing patients for the study. All patients had to sign an informed consent.

Smartphones provided for the study were the Samsung Galaxy S I9000 as a high end device and a Huawei Ideos X3 as a low budget smartphone. Supplied SIM-cards were restricted to the number of the haemophilia treatment center and to the support, and were delivered with an internet flat rate. But all patients were free to use their own SIM-card and/or device if available. The obvious differences of the devices are the quality of the camera, the size of the screen and the version of the operating system. The installed and used barcode scanner couldn't be used with a low budget device, because of the missing auto focus. In this case the batch and pharmaceutical registration number needed to be recorded manually via keyboard or

chosen from a provided list. If the haemophilia treatment center already documented the used medicine, the relevant numbers were directly offered by the application and the patient just had to select them. All other functions were available on high end as well as low budget devices. Recorded data was transmitted over GSM (Global System for Mobile Communications), or WLAN (wireless local area network) to a centralized server, provided to each haemophilia treatment center over the internet (encoded per TLS/SSL-protocol) and could be accessed via Internet browser on every device.

Physicians and nurses in the haemophilia treatment centers were trained for each application. The aim was to train the physicians and the nurses as trainer and so that they could brief the patients by themselves. The training took place locally or by telephone and was supplemented by different manuals in detail for each application. Additional telephone support was provided for physicians as well as for patients.

### 4.2. Results of the Test Period

29 Patients participated in the study. 13 individuals needed a provided smartphone and 16 could use their own device. They did not start on the same date, but got involved over the 6 months.

Characteristics of the patients are summarized in Table 2. In the six months observation period from 20 February till 20 August 2012, 22 patients treated with prophylaxis and the total number of days they were using the electronic diary was 1,990. 7 patients treated in case of an assumed bleeding (on-demand) and counted a total number of 564 active days. During the study 1,003 treatments and an overall consumption of 1,268,000 IU (international units of Factor-VIII and Factor-IX concentrates) and 278 mg (Factor-VII concentrates) were recorded with the electronic diary smart medication. The usual amount of factor concentrates is around 1,500 I.U. per prophylaxis treatment. The costs of 1 I.U. is normally between 80 cents to 1 Euro.

	Prophylaxis	On-demand
Patients	22	7
Days (total)*	1990	564
Days (average)*	~90	~81
Treatments	934	69
Consumption	1,181,500 IU	86,500 IU

\*Total number of days that patients used smart medication

The collected data was merged with the patient's paper diary after the six month period. This comparison proved that no recorded data got lost. In some cases the integrated security functions showed that the patient documented his treatment data in his paper diary but forgot to repeat his documentation in his electronic diary.



None of the patients stopped or had the intention to stop using the electronic diary and everyone continued after the test phase. Only during the selection of patients for the trial some patients refused because of the need to use an Android smartphone. The consultancy of the telephone support was low and most calls were received because of internet connection problems or the loss of the password. But some problems arose because of the inexperience of some patients in the use of a mobile device. For example, apparently easy to use functions such as turning the device on and off, scrolling the screen, removing the display lock, or just accepting an update of the application were unknown and needed to be explained by the support. Some patients were not aware of the need of a working internet connection and disabled it because of the fear of high costs, even if they were using a provided SIM-card. The warranty of the support that even with an application update not more than a few megabytes arise during the use of the application per month were needed in this case. Sometimes a slow internet connection prevented the data from being synchronized, because the user used the device only for documentation and turned off the device before the data was sent. Other incidences were e. g. the use of special characters during the documentation which had to be prohibited because of security issues; the loss of standards and a nomenclature for the batch numbers and therefore faulty insertions because of the missing possibility of verification; the use of a wrong date; the input of the same treatment data twice; the use of the wrong URL (uniform resource locator) to download the application; etc. [9].

Besides these requests for support all patients were able to document all treatment data with the electronic diary without difficulties. We could prove that no treatment data got lost, even patients with no experience with electronic devices can use the system with the help of a simple telephone support, and that the patients are willing and happy to use an electronic diary. In the beginning some patients needed to be convinced that the use of the application would not take more time than the use of a paper diary. Even with the advantages of having all treatment data digitized, the possibilities of a real-time monitoring by the doctor and the allocation of reports and analyses, some patients did not want to use the system, if it would take more time to document the treatment data with the electronic diary instead of using the paper diary. For example simple inputs such as the weight needed to be saved so that the user did not have to enter it every time.

The two aspects which became obvious during the six month trial were firstly, the need to keep the application as simple and easy to use as possible, because complexity prevents the patient from using it. All functionalities which are not necessary will just make the application more confusing. Secondly, that it is necessary to support more than one platform, because many smartphone users are not willing to change the brand and do not want to carry another mobile device besides their own.

### 4.3. Extension of the Test Phase

After the experiences of the first six months, the applications were developed further using HTML5 and the framework Sencha Touch to make them usable on almost every device. Defaults were adjusted, the functionality adapted to the simple needs of the patient and the instructions manual revised specifically with regard to the recorded incidents.

From September 2012 to February 2014 the operation of smart medication was extended in Germany and also to Austria and Switzerland. Overall, 25 haemophilia centers and 257 patients were already set up and had access to smart medication. Of all patients only 46 needed a provided smartphone and 211 patients are using their own mobile device, a laptop or desktop computer. Until February 2014 over 18,750 treatments and a use of more than 24,300,000 I.U. of factor concentrates were recorded via smart medication.

## 5. DISCUSSION

Chronic diseases such as haemophilia require some of the most expensive patient-centered care in the health care sector. For example, a patient with haemophilia uses an average amount of medication with costs of more than € 53,000 per year for his entire life. This means for around 4,000 patients with haemophilia in Germany a need of at least € 212,000,000 just for medication per year [29]. Following treatments because of bleedings, lost time injuries, hospitalization, surgeries and invalidity are not included. One patient can even cost several million euros per year. Small insurance companies were almost insolvent because of the requirements of one patient with haemophilia in the past. Therefore possibilities for therapy optimization promise not only a higher quality of life for the patient but also save money. Telemonitoring provides an optimization of therapy with an optimal and cost efficient application of coagulation factors.

Former studies already showed the great potential of telemedicine. The survey called "VDE-Studie – Pro TeleMonitoring" by the company "VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V." published in October 2012 analyzed several national and international studies about telemonitoring. It proved that the use of telemedicine for chronic diseases increased the quality of patient care and his compliance. With it, telemedicine reduced the risk factors for hospitalization and serious following complications, because of the early notification of complications and abnormal trends. This causes extensive economies of 10% to 50% in routine treatment and up to 70% for stationary treatment. But for all this there is still no billing code for the use of telemedicine in the health care sector in Germany. The doctor's service cannot be billed and therefore, the spread of telemedicine and the motivation of the doctor to launch new technology are rare [30].

This paper showed the importance and advantages of telemedicine for patients with chronic diseases using the





example of a running telemonitoring system for patients with haemophilia. From 2011 to 2014 a telemedicine platform for real time surveillance of haemophilia home treatment called smart medication was developed, tested and rolled out in collaboration between medical and IT experts, researchers and patients.

In 2012 a 6 month test period helped to identify requests, needs and technical difficulties of patients and physicians. It could be proved that mobile devices are predestinated for the use for telemonitoring. No patient stopped or intended to stop the use of the application. Barriers in using an electronic device could be overcome even by patients with a higher age, who had never even used a computer or an electronic device before. Implemented security functions proved the safety of an electronic treatment diary and that no recorded data can get lost. But the trial also showed the difficulties such as the big and fast changes of technologies and therefore the continuous need of enhancement. Patients want to use only their own smartphone, they neither want to carry a second device, nor change the brand of their used phone. Everything that overloads the application or requires more time for documentation can bring the patient back to using the former paper diary. The aim has to be a fast and easy to use application, with a simple and intuitive user interface, an implementation of patients and physicians needs only, independence from all pharmaceutical companies and with it open for all concentrates, and with availability for almost every device such as smartphones, tablets, laptops and desktop computers.

After the 6 months test period the applications were redesigned on the basis of HTML5 to provide platform independency. The number of users was increased to the total amount of 25 haemophilia treatment centers and 257 patients in Germany, Austria and Switzerland in February 2014 and is still growing constantly.

A current limitation of this study is the focus on one system for one chronic disease. But the needs of patients with different rare diseases are mostly the same: optimal und continuous care. Also the barriers and difficulties in developing a telemedicine platform are comparable in reference to requirements and restrictions, usability and performance, policy and procedures, law and financing.

## 6. CONCLUSIONS

The use of an electronic diary enables a location independent real-time surveillance of home treatment. Further studies reported that patients are willing and capable of using mobile devices for treatment documentation [14; 20] and were affirmed by this study that a telephone support is adequate to assist patients and physicians in using mobile applications. Integrated security functions demonstrated that no recorded data is lost.

The 6 months trial indicated that the real-time transfer and analysis of treatment data has advantages over paper. The immediate evaluation of the bleeding data can assure the effectiveness of the therapy. Despite the short time interval of six months e.g. the collected data not only showed that patients on a prophylactic treatment bleed less than patients treated on-demand but also used almost one-third less factor concentrates. No data needs to be digitized manually which means a big gain in time and costs.

In conclusion the use of modern mobile technologies can help to identify every abnormality without delay. The therapy can be adjusted by the physicians without the need of local consultation. The results of the study already illustrated that an electronic system can increase the quality of surveillance, enhance the life quality of the patient, and optimize the therapy, within an adaption to an economically optimized factor concentrate use.

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