AHRQ Final Report

Title of the project:
Virtualized Homes: Tools for Better Discharge Planning

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Structured Abstract:

Purpose:
The goal of this project is to evaluate the technical feasibility and potential clinical value of integrating a full-scale 3D model of a home into the clinical workflow.

Scope:
Better understanding of a patient's residence can enhance tailoring of home-based self-care and disease management interventions. Nowhere is this more important than in the discharge planning process. We propose a proof-of-concept technical innovation that will enable clinicians and patients to easily visualize the interior of the patient's home, make plans that compensate for or take advantage of features of the house and allow storage of annotated images of the home in the patient's electronic health record (EHR).

Methods:
We developed a point cloud viewer in support to the creation the models of patient's homes. We examined the feasibility of integrating the o full-scale 3D model of a home into an electronic health record and the clinical workflow. A focus group was conducted to evaluate the desirability and usability of the services.

Results:
We developed the capacity to capture and render 3D models of actual homes and demonstrated the feasibility of embedding these models into the electronic health record (EHR). We explored their usability for clinicians or health care providers involved in transitional care. Focus group participants described issues with information acquisition; usefulness for complex discharges, 22 patient characteristics, and the use of the HOME3D viewer as a collaboration tool among clinical providers.

Key Words:
Virtual reality, 3D visualization, electronic health records, discharge planning, preventive care.

Purpose (Objectives of Study)

Successful transition from hospital to home requires good discharge planning. Too often discharge planning occurs abruptly and lacks an understanding the patient's home situation. In Wisconsin, almost 20% of discharged patients are readmitted within 30 days; the average cost of an unplanned return to the hospital is almost $10,000. We believe that many of these readmissions could be prevented by better understanding of the place where the patient's home environment. We proposed to develop computer models of the patient's home that could be to aid in discharge planning. In this project, we evaluated the technical feasibility and potential clinical value of integrating a full-scale 3D model of a home into the clinical workflow.

Frequently, discharge planning focuses on health problems and disease management, such as medication taking and dressing changes. The transition from hospital-to-home can be hampered by a lack of understanding by clinicians and patients about how to organize the home to facilitate home-based care. Verbal descriptions and snapshots of selected places do not do justice to the experience of being in a crowded bedroom trying to find a place to store medications or standing at the foot of a long hallway to the bathroom, wondering if one's walker will fit through. There is evidence that better understanding of the physical characteristics of the home (clutter, stairs, room layout) may lead to more concrete planning of discharge actions and greater success in successful transition to the home, reduction of readmissions and better health outcomes.

Specific aim:
Discharge planning efforts could result in actions more tailored to the patient's life if there were better understanding of the patient's home situation. The specific aim of this pilot project is to demonstrate the technical feasibility and clinical value of making a full 3D model of the home available for exploration and annotation during the discharge planning process and including a highly detailed set of images of the patient's home in the electronic health record (EHR).

Scope

One in five patients discharged from Wisconsin hospitals returns to the hospital within 30 days. These readmissions are hard on patients and place the institutions at increased financial risk for uncompensated care. Strategies that can improve the success of discharge are likely to be both cost effective and satisfying to the patient. Most efforts to improve the discharge process focus on in hospital communications among providers (YALE CORE, 2013).

Most of the work planning discharge involves in hospital coordination of teams or ensuring effective health information exchange (Vest et al 2014). Lippin's group expanded that to include patient workflow assessment (Lippin et al 2014). Metanalysis determined that context aligned interventions were best at reducing hospital readmissions yet the only strategy for understanding the context was home visits. These visits identify not only limitations that must be managed but may also identify assets that can be exploited to reduce the demand that home care interventions place on people in the immediate post discharge period.

Better understanding of the home could occur through a variety of means, including conducting home visits. This does not resolve other challenges at the point of discharge 1) enabling an exploration of the home environment involving the resident and the clinical team (Okoniewska et al 2015) and 2) documenting the household exploration in the EHR (West et al, 2014). Thus, direct home visits may not only be infeasible but may not yield a sufficient record of the visit and its decision.

Other approaches for acquiring and later viewing home data include creating a collection of photos or videos (Naylor et al 2014). Neither of these options allow for interactive exploration, important detail is easily missed or obscured and taking comprehensive measurements is not trivial. We propose a technically more robust and more flexible solution at the point of discharge planning. Pictures and videos depict only the perspective of the person taking the picture or shooting the video; the method that we will use allows the nurse and patient to move around the room viewing the space at multiple heights or angles, thus affording flexibility to "see" the room while sitting in a wheelchair or from the perspective of a child.

Our goal in this project to provide specialized computer support to clinicians and patients when an exploration of the physical layout of the patients' home can enhance the discharge planning process and to store a record of that exploration in the EHR for future reference by patients or clinicians. The work built on previous AHRQ funded efforts and leveraged our established partnerships with UW Health and Epic Systems.

Supported by a grant from AHRQ (HS 22548, vizHOME: a context sensitive health information needs assessment strategy), our vizHOME teamexplored how the home context shapes health information needs. We have successfully scanned the interiors of 18 homes, creating large data sets called *ppoint clouds.* We developed ways to display the point clouds as full-scale models of those homes on standard computer monitors and in immersive 3D environments (see Fig. 1). With our full-scale house models, we were able to virtually walk through a room and view the space from novel viewpoints independent of initial camera position. This robust visualization flexibility allowed a more in-depth exploration than possible with pictures or movies, allowing the person looking at the scene to explore parts of the household a video flythrough would have missed.

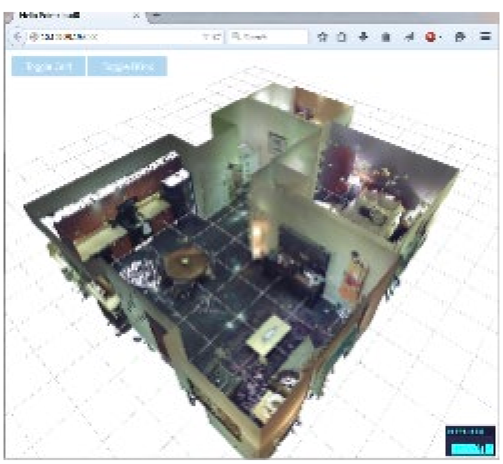

Fig 1: Prototype of the web-based viewer, running inside the Chrome browser and displaying the point cloud created from SON's simulated apartment.

Settings:

Clinical decision making is enhanced when appropriate information, such as laboratory results and radiology images, are integrated within the electronic health record. In collaboration with our clinical partner, UW Health, we worked on simulated Epic environment to integrate home images to the clinical system through a tab access to display, manipulate and annotate the images in a web browser.

UW Health is the academic health system for the School of Medicine and Public Health of the University of Wisconsin-Madison caring from more than 600 thousand patients each year. UW Health adopted the Epic Systems Corporation electronic health record in the early 2000s. The data from the Epic system is also stored in an enterprise data warehouse, which supports the use of electronic health records data for clinical operations and research. Focus groups were conducted in the School of Medicine and Public Health and had the participation of UW Health employees.

Methods

In the HOME3D project, we focused on finding an efficient way to store the large data sets generated for each home in a secure way that makes them accessible from within the EHR, while not requiring that all of the data to be stored in the EHR, and resolving issues such as identity management, privacy, rendering efficiency, data storage and transmission speed. The project was composed of four general steps in this project: 1) Requirements Definition, 2) Proof of Concept, 3) Stakeholder Assessment and 4) Resolve Technical and Policy issues.

1) Requirements Definition: We conducted a focus group with clinicians who were the likely users of the home visualization, such as discharge planners and care management clinicians. The second will target patients. The clinician focus group addressed five questions: In your practice, to what extent does success or failure of discharge rest on understanding where the patient will reside after discharge? How do you currently get information about post discharge residence? For what kinds of patients is the discharge to home process particularly challenging? What kinds of activities must be designed mindful of the patient home? How can the results of our work best be presented back to you?

We worked with UW Health teams, particularly with UW Health Chief Medical Information Officer (CMIO), to identify a candidate list of clinicians. The UW Health CMIO made the first approach by email, introducing the project. The UW Madison Survey Research Staff (SRC) solicited and organized the meeting. A 90-minute focus group was held and conducted completely by the SRC. Initiating phone calls to individuals were made by the SRC. Clinicians were compensated a modest amount for their time and effort. The study was approved by the University of Wisconsin - Madison Institutional Review Board (IRB).

2) Technical Proof of Concept: Figure 2 shows an overview of the proposed technical proof of concepts aspects of the project. The scanning and preprocessing steps create the point cloud data set of the home (A) which is uploaded to a storage server (E). An identification and authorization link are created for the EHR. Clinicians are able to access the data using a web viewer (B) that opens from the main screen of the EHR and permits annotation (C) and export of a 2D image for EHR storage (D). The EHR is updated with a copy of the annotated image (E). Much of the work in this step occurred in the laboratory at Wisconsin Institute for Discovery (WID) and UW Health/Epic simulation environment.

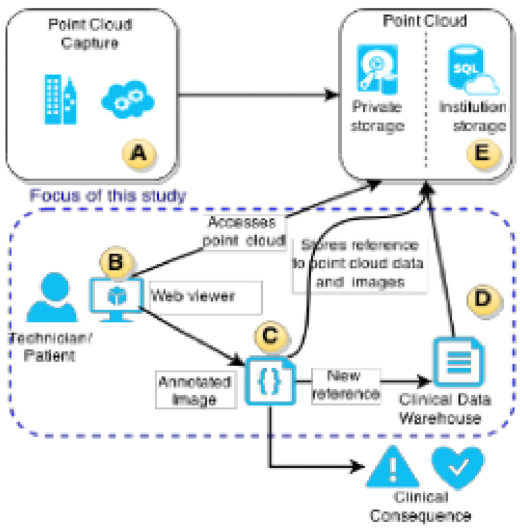

Fig. 2: Proposed Technical Proof of Concept

Fig 3: A mock-up of an annotated image, the expected output of the web-viewer.

3) Clinician Assessment of the User Interface: After implementation, integration and display of the house data was validated, the UW SRC we conducted a stakeholder focus groups with clinicians. We explore their opinions of the type of patients for whom this resource would be of assistance. A key output of this phase was a preliminary assessment of the usefulness, utility and acceptability of virtualizing homes for clinical care.

4) Address technical and policy issues for future work: We kept a running list of technical and policy issues. We met quarterly with the UW Health and Epic teams and leveraged their knowledge and understanding in this area. During these meetings we reviewed and discussed progress. Our partners had very distinct roles regarding technical and policy: Epic advised and helped with the technical and policy implementation of storing and retrieving the data; UW Health and UW SRC helped refining the workflow to explore the point cloud data and annotate the image.

3) Clinician and Patient Stakeholder Assessment of the User Interface: After integration and display of the house data was validated, the UW SRC will conduct a focus groups with clinicians. We explored their opinions of the type of patients for whom this resource would be of assistance. A key output of this phase was a preliminary assessment of the usefulness, utility and acceptability of virtualizing homes for clinical care.

4) Address technical and policy issues for future work: We kept a running list of technical and policy issues. We drew from our national networks to keep abreast of policy developments that influence the acceptability of the work. We me quarterly with the UW Health and Epic teams and leverage their knowledge and understanding in this area, and review and discuss progress. Our partners had very distinct roles regarding technical and policy: Epic advised and helped with the technical and policy implementation of storing and retrieving the data; UW Health and UW SRC helped refining the workflow and to explore the point cloud data and annotate the image.

Overall analysis plan:
The analysis for this project relied on descriptive statistics and qualitative approaches. There were two types of analysis activities, technical and operational. The technical analysis provided performance benchmarks and validation evidence (e.g. file size, transmission rates, visual presentation accuracy, latency, etc.). The operational analysis activities generated evidence of the requirements, the acceptability of the home visualization to clinicians and patients and a preliminary enumeration of the patient types (e.g. diagnostic code, functional status) most likely to benefit.

We conducted a thematic content analysis of the focus groups. We identified categories, recurrent themes and trends that emerge from the interviews. We assessed similarities and differences between participant answers, emerging categories or themes and ranges of variation among them. We also identified new trends and examined patterns of emerging themes. We used NVivo 10 to facilitate the thematic coding of the focus groups and interviews.

Results

HOME3D solution:
HOME3D neatly extended the existing VizHOME project by providing access to captured point cloud data to health care professionals though modern EHR implementations (Figure 4). This section addresses both the technical and clinical aims of the projects. The figure below shows an overview of the goals.

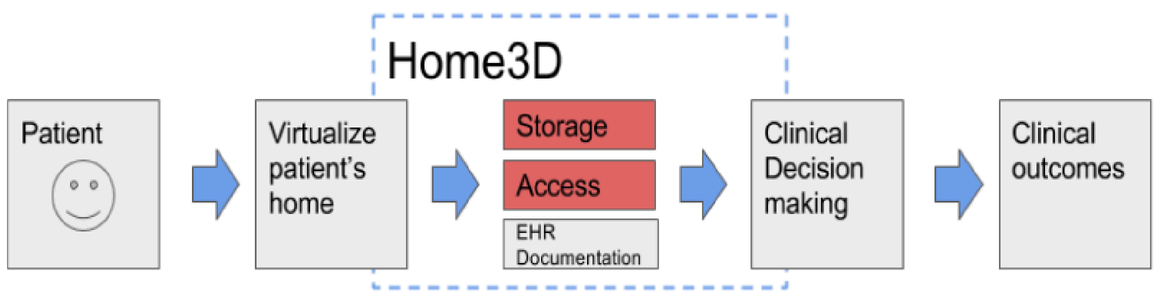

Figure 4. Overall schema

In means of integrating these pointcloud datasets into the electronic health record (EHR), a proof-of-concept web-based viewer was developed. The viewer was implemented using WebGL and Javascript and supports all modern web-browsers and mobile devices. The point of cloud models, consisting of hundreds of millions of points of home environments, were created using a state-of-the-art Lidar scanning. The web-based viewer allows the clinician to navigate around the 3D point of cloud using a regular mouse and keyboard in real time. While the clinician is navigating the model within the EHR, a sub-sampled version of the scene is presented to the clinician. When the clinician ceases navigation, additional points are rendered that add detail to the visualization for enhanced analysis. Other features, such as copying the image, mark objects and associate with labels and measuring distance between objects are provided. The HOME3D viewer was interfaced with the Epic clinical record and demonstrated an interoperable data storage strategy. Still images from the views were exported on demand and stored back in the EHR where they were annotated and processed.

Figure 5 shows the data flow in this project. We create, process and store both 3D point cloud data as well as textual metadata, based on the Getty Art & Architecture Thesaurus to describe the home environment. Workflow integration and the use of the viewer as depicted in Figure 6. The primary output are static images which are then imported into the EHR for further annotation, record keeping and dissemination.

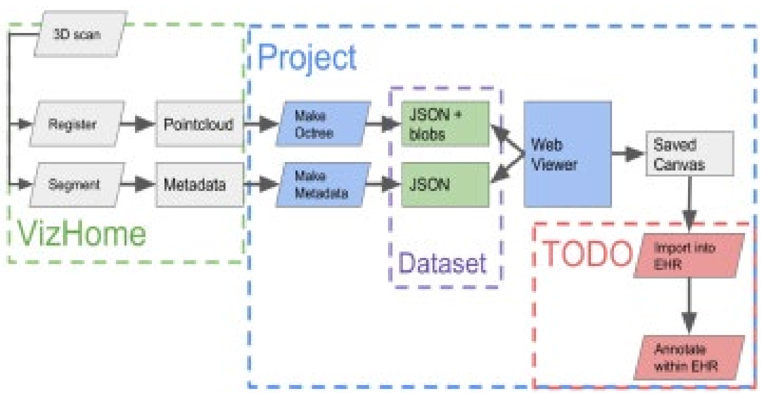

Figure 5. HOME 3D Data flow

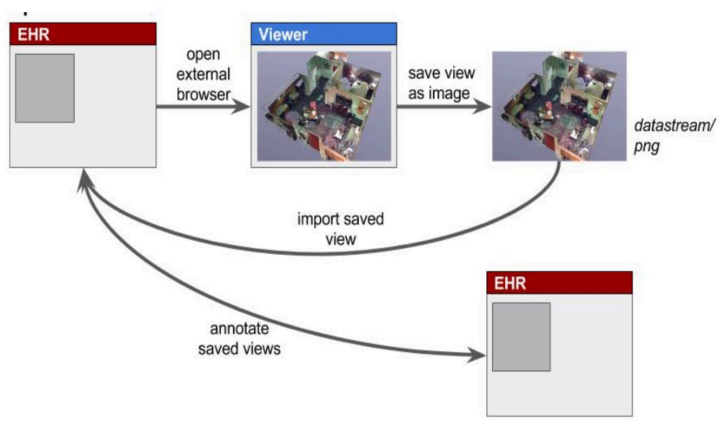

Figure 6. HOME 3D Workflow

Focus group outcome:

Focus groups participants were positive about the technology and its usefulness for planning and preparing patients for discharge. Key themes raised included: 1) issues with information acquisition; 2) useful for complex discharge as defined by the degree of illness burden, rehabilitation, rehabilitation requirements, and characteristics of the home (by patient report), i.e. not all patients would require scanning; 3) patient characteristics and issues; and 4) use of the HOME3D viewer could enhance collaboration among therapists and across therapies (Table 1). Therapists recommended in addition to the ability to view the actual home with patients, that the home models also be viewed by any health care providers who would be making home visits.

Table 1. Focus groups themes

Acquisition	Complex Discharge	Patient Characteristics	Collaboration
Information gaps	Illness severity	Reliability	Team interview
Contradictions	Home characteristics	Communication	Mutual problem-solving
Uncertainty	Rehabilitation	Memory	Reduce errors
	Requirements	Pain level	

Acquisition Issues

As with any type of interview, several factors affect acquisition of information. Inaccuracies may result from those who are communicating, a loss of information in the exchange or misunderstandings. Comments from the focus groups follow in single quotes and in italic. Therapists reported that they currently do chart reviews 'when the chart is available' and ask patients and family about pertinent home information. When more than one therapist requests information from patients, they may receive conflicting responses. Other people may interview patients about their homes, but 'may not know what to ask'.

Complex Discharge

Determining the level of complexity involves considering if the patient even has a home and what the conditions of the home are. According to one participant, 'That's hard to make that call if they're safe when you don't really know what their environment is that they're going back to'. The presence or absence of a support system both in- and outside of the home is also a concern, as one participant gave the following example 'Oftentimes I'm recommending like this dresser should be moved two feet this way, or this king-size bed needs to be moved eight inches that way. But it's myself and a 90-year-old man in the house'. Further, the type, size and condition of the house affect the ease of transition and of following a rehab plan in the home, e.g. 'anybody with a mobility deficit needs some level of assistance, physical assistance from somebody else or assistance from a device'.

Patient characteristics

A question of primary importance in determining discharge disposition is the condition of the patient in his/her home environment. Often discharge planners 'We lean heavily on family members to get as accurate of picture as possible of the home situation. If you're lucky, you'll get a family to take cell phone pictures for you and show them to you. Patients may also not present an accurate picture of their home environment, not necessarily with in an intention to deceive, but perhaps a failure to notice or a lapse in communication. Often times patients aren't necessarily reliable or not able to communicate' effectively.

Collaboration

When describing collaboration among therapists and across therapies, focus group participants pointed out that use of HOME3D could promote collaboration between inpatient and outpatient therapists saying 'This could help the inpatient therapist...to tailor the treatment to what the patient's going to need at home. You might change what you do based on what you know the patient is going to have to do at home'.

Conclusion:
The presented solution for virtual environments is able to overcome these limitations through a progressive feedback driven rendering scheme. The results show that the generated method provides a better overall experience. An approach for web-based viewing has been integrated as a proof of concept into EHR with success.

Despite the excitement about VR-based simulation in healthcare many challenges remain. First, little is known about what aspects of the simulation contribute to learning and transfer of learning, critical to rehabilitation. The primary reason why existing VR scenarios do not scale to the clinical needs of a broad range of patients awaiting discharge is that they are very specific to a given task in a given environment, usually a laboratory or clinical setting. In traditional, task-based simulation all participants receive the same visual cues; nuances and context are lost. The range of risks for readmission is substantial; it is impossible to build a simulation to specifically address each one. Our context-focused simulation approach, in which the simulated environment is the re-creation of the actual home, will allow the maximum tailoring to the individual patient. Future work will aim to better understand the experience of the end user, develop ways to measure the quality of the rendering system during motion, and explore alternative sampling strategies for accelerated convergence.

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List of Publications and Products (Bibliography of Published Works and Electronic Resources from Study—Use AHRQ Citation Style for Reference Lists).

Publications:

Broeker M., **Mendonca EA**, Brennan PF. HOME 3D: Virtualized Home Environments in the EHR. Proceedings of the 2016 AMIA Annual Fall Symposium. 2016. Washington, DC. p. 1351

Seminar presentation:
Mendonca, E.A.; Ponto, K. Virtualized Homes: Tools for Better Discharge Planning. AHRQ National Webinar on the Use of Health IT to Improve Care Planning and Communication with Aging Adults. July 17, 2017.

Demonstration:
Live demo of a LiDAR scanned home environment (Accessed November 10, 2018)
https://blogs.discovery.wisc.edu/public/demos/Home3D.test/viewer.html?id=son5

Electronic resources:
Source code is available at: https://github.com/broecker/home3d-viewer
(Accessed November 10, 2018)