1. Improving image guidance in interventional radiology: information lack in transjugular intrahepatic portosystemic shunt

CF Cuijpers 1, E Varga 3, PJ Stappers 4, A Freudenthal 5, Industrial Design Engineering, Delft University of Technology, Delft;
A Moelker 2, Department of Radiology, Erasmus Medical Center, Rotterdam.

1.1 Introduction

Interventional radiology is a fast growing subspecialty in radiology. The physician navigates with instruments (e.g., needle, catheter) through small incisions in the patient's body. This is done for treatment purposes. In addition, the physician is guided by artificial images (e.g., ultrasound), created before or during the procedure [3]. One of the most technically challenging procedures in interventional radiology is the creation of a transjugular intrahepatic portosystemic shunt (TIPS) [5]. In TIPS, the interventional radiologist (IR) navigates instruments through the patient's body to create a shunt (using a metallic stent) within the liver to connect the portal vein to the liver vein (hepatic vein) or hollow vein (vena cava inferior) [2]. This is done to regulate bloodflow in patients with portal hypertension. The procedure may be lifesaving, but also risky and several types of complications can occur. Complications mainly occur during the intrahepatic puncture of the portal vein (e.g.,[4]) and are especially related to the limited information from image guidance (two-dimensional, not real-time [8]). The paper of Adamus et al. mentions that even experienced TIPS centres need less than five puncture attempts in only 25% of their procedures [1]. Generally, TIPS takes several hour, while with one effective puncture a procedure could be successfully completed in one hour [4].

Our project team aims to reduce the number of complications and the procedure time, by creating an image guidance which better fits the physician's needs in making one successful puncture. To achieve this, a rigorous analysis of the procedure, the workflow, and the physician's needs and cognition in this early design phase is needed (e.g.,[14]). The analysis should generate insights into information needs, the decision making process and cognitive interaction constrains [9][12][16]. These insights could help the engineers in the multidisciplinary team in understanding how the user interface could be improved to create a safe and reliable information system [16] that physicians like to use [9][12]. Furthermore, the insights could support communication between the team members (engineers, physicians). Communication with the end-user is essential, because to decrease the TIPS complications and create user satisfaction of the product, the user should be represented in the design process [11]. The aim of this research is to find criteria to support physician's decisions making process, and to find ways of assessing and improving the TIPS image guidance information lacks.

Currently, methods such as ethnographic techniques (e.g., observations, interviews), questionnaires, or activity tracking are used for work analysis (e.g.,[14][16][17]). However, these methods mainly provide explicit and observable knowledge [13], but according to Melles et al. (2003); 'participants are not always aware of their exact needs, or may not

regard particular pieces of information as useful to the study'. Contextual research methods assist participants to recognize and express their tacit knowledge [13]. Participants are first stimulated to become aware and reflect on their experiences, and make their understanding explicit with visual means, which they then explain and discuss. Then, considerations, needs, and values become explicit and open to discussion. These can now be communicated with the design team, which can then take into account participants' knowledge, experiences, skills, abilities and limitations. For the contextual research cultural probes, generative tools, and focus group interviews can be used [11][13]. Before, the techniques were used in some medical domains (e.g., [11]), but hardly in interventional radiology [10] and, according to our knowledge, not in the TIPS context.

1.2 Method

The study started with a literature review in combination with an ethnographic study of TIPS. Literature brought up medical and technical aspects, but little can be found on design considerations and task demands of guidance interfaces. Ethnographic methods provided better understanding of the procedure, context and end-user. However, it appeared that in the minimally invasive TIPS procedure little can be observed, and that IRs knowledge is mainly implicit. For this reason, the engineer still had difficulties to understand the complex procedure, had problems in formulating questions that provoked useful answers, and the IRs could not recognize what the engineer needed to know. To gain deeper insights, contextual research methods were applied, to make physician's tacit knowledge more explicit.

Contextual research methods: The tools described by Sleeswijk Visser et al. (2005) [13], and Meijs et al. (2008) [10] were adjusted to best fit the availability of the physicians, and to create focus on physicians' perceived difficulties of TIPS procedures. Individual generative sessions (60-90 minutes) were organized, with six male IRs from four different Dutch hospitals. To prepare the IRs for the session, the participants were asked to fill in a preliminary booklet, which they received one week before the session. The booklet contained three assignments about interventional radiology. During the session, participants were asked to draw a timeline of one particular TIPS (Fig. 2-1). On the timeline they had to 1) write down the different steps in TIPS, 2) mark the most crucial part of the procedure, 3) note down the difficulties, and 4) things that helped them to overcome those difficulties. For these four assignments, the use of drawings and images was stimulated, by providing coloured pens and a prepared set of stickers of ambiguous words, and images meant to trigger relevant areas of considerations. Subsequently, the participants were asked to discuss their created timeline with the moderator, and as a result extensive discussions took place.

The sessions were recorded, transcribed, and analysed. Selected quotes were printed, and their relevance to the design goal was discussed. The prints were clustered to expose patterns. For each cluster, an appropriate theme (and subtheme), was defined. The main themes were: aim of the procedure, patient, navigation, perceived difficulties.

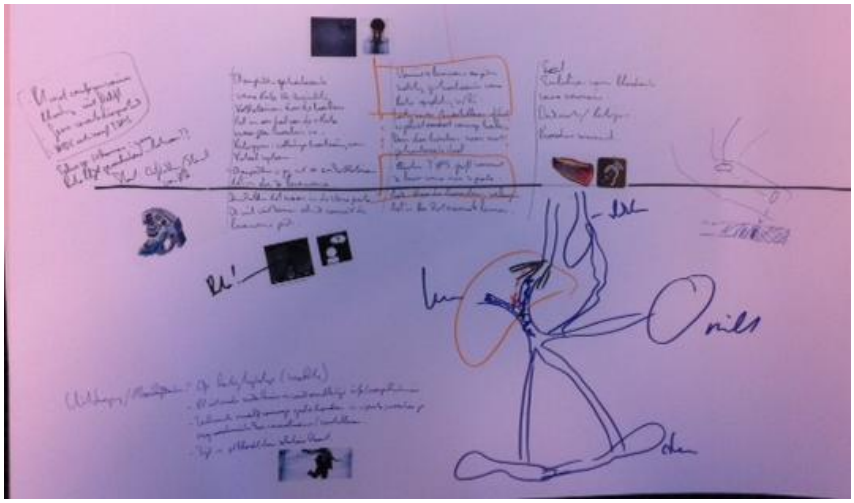

Figure 2-1. Example of a participant's TIPS timeline, created during a generative session

1.3 Results

A IR divides TIPS in a preoperative, an intraoperative and a postoperative part. Participants emphasized the importance of the first part, since a carefully prepared procedure reduces the chance of mistakes. To describe the intraoperative part, participants listed up to seventeen observable, physical 'macro steps' on the timeline (also defined as tasks in literature (e.g., [14])). In general, those macro steps are (Fig. 3-2): catheterize the hepatic vein, puncture the portal vein, place the stent between the portal vein and the hepatic vein, and check new blood flow. All participants identified the portal veinal puncture as most complicated: "…the difficult part of the procedure".

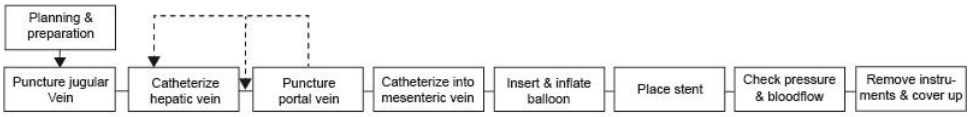

Figure 3-2. Simplified workflow with macro steps, dotted loop represents the repetitive punctures.

While discussing the TIPS timeline, it became clear that IRs are dealing with many more steps during the procedure (unknown number). These steps, which are small, hard-to-express, and unobservable, will be launched as 'micro steps', and will be defined as the elementary cognitive actions a physician has to make to carry out one macro step. Micro steps can be divided in micro actions (e.g, place the catheter in the right direction), or mental micro questions (e.g., where is the target vein?). Throughout a procedure, a physician questions himself different mental micro questions (tries to get information from e.g., the user interface), followed by several micro actions, and only then he is able to complete one macro step. During the generative session 64 of the mental micro questions were revealed. In 26 out of 64 questions, the physician can find the proper information to answer the question, for 31 of the questions no information can be found at all (Table 3-1). IRs miss feedback information on exact anatomy and instrument location and feedforward on instrument use and control, and how to perform a next puncture attempt. For 7 questions only limited information is available. The information which is actually provided to the physician -visual and/or haptic- is mainly provided after the performed action, and not beforehand. For example, an IR will assess how much force to apply on the needle.

However, only by trying he will see how the needle moves, and he will know whether the right amount of force was applied. If not, structures can be harmed and serious complications can occur (e.g., rupture of the vein). Furthermore, the available information is often indirect, and as a result physicians are frequently unsure if they interpret information correctly: “You ask yourself what you are seeing”.

Mental micro question	***Information?***
Why did I not puncture the PV?	No
How can I improve my puncture?	No
Did I puncture inside the PV?	Yes
How to position/turn/shape the instruments to create the desired angle?	No
Do I not use too much X-ray?	No
How do I still get access, after instruments got stuck?	No

Table 3-1. Information availability for some of the identified mental micro questions, when trying to gain access to the portal vein.

When answers to mental micro questions are unavailable, physicians are forced to make decisions solely based on their anatomical and procedural knowledge. Participants reported to mentally project the anatomical representation in their head to the X-ray images and then estimate how to perform the micro step: “I just know where it [portal vein bifurcation] is approximately located…”, “…we reconstruct in our head.” The information provided after the action only indicates if the action was successful or not, and provides marginal guidance for a next attempt. This makes the procedure a process of trial and error: “You do not know exactly where to go, it is ‘God save me from troubles’ and try as often as needed.” The limited amount of information normally leads to multiple trials to puncture the target vein, increasing the procedural time and the amount of risks. When complications occur, the physician is expected to consider alternatives, and “to be prepared to also solve those complications.” Unfortunately, the information lack can make it challenging to solve complications. Overall, the procedure is experienced as stressful and difficult: “..and at a sudden moment it [the liver] becomes a pincushion, which is completely torn apart, and that will make me sweat.”

1.4 Discussion

The results show that the lack of information is mainly observable at micro level, as insufficient information is provided to effectively perform the micro steps. Micro steps are the building blocks of macro steps, and crucial for the navigation process within the patient’s body. This explains why TIPS is complicated. The interface should thus provide the information needed for the micro steps (Fig. 4-3).

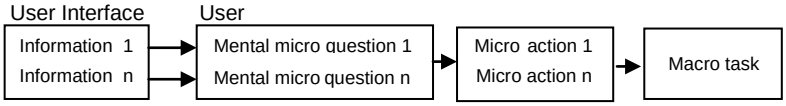

Figure 4-3. From user interface information to macro task.

Obviously, task analysis of observable processes, but also of unobservable processes and cognition is crucial, before one is able to improve a user interface [16]. Little information is available for medical domains (e.g., surgery, chronic disease clinics) [14], but not for interventional radiology [15], and especially not for TIPS. The current research is the first to unveil information needed to improve TIPS.

In TIPS, physicians largely depend on their own knowledge and estimations, and only very experienced IRs can perform a TIPS procedure. However, even for experienced IR, correct decision making remains difficult. Hollnagel et al. (2007) mentions that decisions should be sufficient, rather than complete [6]; however in TIPS, decisions are not even sufficient. A trial and error approach –ending in a final decision- is very time consuming and leads to unnecessary complications. Therefore, a user interface should be designed which better supports physicians decisions making [15]. Based on Jalote-Parmar et al. (2007) [7] we point out that the desired information should be provided 1) for each and every micro task 2) when the physician is confronted with the task 3) in a way that meets the physician's cognitive and visual requirements.

Although, several methods were used and needed for this paper, especially the generative method unveiled the information lacks of current image guidance. The method helped both the engineer and the participants to obtain an improved understanding of the procedure and of the physicians' cognition. Probably, not only because participants had to present their experiences, but also because the set up of the generative session: participants were not restricted by specified questions, but invited to have an open, controlled discussion. The task was leisurely done, and participants were free to express their opinion. Besides, physicians' output served as an input for the researcher, which could immediately raise new questions. The use of following ethnographic methods became more effective after the session than they were before: observations were easier to follow, and more detailed questions could be asked. Overall, the generative sessions worked as a catalyst, instantly raising engineers' understanding of the procedure. As a result the communication between the engineer and the physician became more effective.

In future research, action research is planned to convert the obtained data into iteratively prototyped and tested image guidance. During this process, we will work in a multidisciplinary team. We are convinced that the improved understanding will facilitate the communication with the end-user, but also amongst end-users, and will contribute to a more efficient end-result in which an image guidance system is developed that meets the physicians' desires in function and use.

1.5 Conclusion

This paper unveiled what information is lacking in TIPS procedures. The generated micro steps clearly illustrate the information the user interface should provide to resolve the difficulties of this complex procedure. Generative sessions appeared to be very useful in revealing the implicit clinical knowledge of a difficult procedure. Next to TIPS, we expect that such sessions -between designer/engineer and end user- can be used for other complex medical domains as well, but also for interface improvement for domains such as aviation or power plants.

1.6 Acknowledgement

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1.7 References

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