

Redesigning reusable surgical gowns: usability and innovation for sustained adoption

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ABSTRACT: To support the transition towards a circular economy in hospitals, this qualitative study aimed at understanding how the adoption of reusable surgical gown can be facilitated. It investigates design features that enhance usability and promote sustained (re)use. A wearing test identified difficulties in wearing reusable gowns. Data collection included observations of 34 surgeries and a survey completed by 73 respondents. Thematic analysis revealed opportunities to improve usability, such as optimising packaging to speed up donning, a wider neck opening to reduce discomfort, and incorporating ‘tearable’ closures to simplify doffing. Innovation strategies relevant to the users involve thermal regulation, monitoring gown performance, and including reusable gowns in custom procedure tray packaging. These findings are discussed in relation to design adjustments and value-chain partners.

KEYWORDS: circular economy, reusability, human behaviour in design, healthcare design, innovation

1. Introduction

To lessen the healthcare sector’s contribution to global greenhouse gas emissions, which currently stands at 4.4% (Karlner & Slotterback, 2019), the adoption of reusable surgical gowns offers a significant opportunity (Harding et al., 2021). By reducing waste and the associated emissions, this shift contributes to a more sustainable healthcare system (Vozzola et al., 2020). Sterile gowns are worn to protect the patient against infections during surgical procedures and are classified as Class I devices under the European Medical Device Regulation (European Union, 2017). Disposable surgical gowns are made out of nonwoven fabrics, while reusable gowns are made out of densely woven polyester filament with a carbon fibre (Behera & Arora, 2009). Despite the environmental benefits, the use of reusable gowns remains rare. To research how the **transition to reusability can be facilitated**, in this study, an exploratory study is conducted combining user-centred design and Rogers’ (2003) Diffusion of Innovation theory to understand user adoption (Parmar, 2017). To encourage long-term use of reusable products, Herweyers et al. (2024) emphasize that human behaviour and situational factors are crucial for embedding these products into daily routines. To achieve this, insight into the human behaviour and habitual processes (Klöckner, 2013) is needed, instead of focussing primarily on technical specifications. Building on van Nieuwenhuizen et al.’s (2023) study on the comfort of reusable gowns, this research investigates how reusable gowns can be designed to **optimise usability**, foster trust, and encourage sustained adoption. By trying the reusable gowns, users have the opportunity to experience and test them, allowing them to form ideas on how it fulfils their needs (trialability) (Rogers, 2003). This allows us to gather insights to assess usability and define design recommendations for the creative design phase as described by Parmar (2017).

1.1. Research aim

We aim to understand how a successful adoption of reusables in healthcare can be facilitated. By means of a case study with surgical gowns, we evaluate the usability of the current design of reusable surgical gowns to identify **design recommendations** that enhance ease of use and safety during their application. Secondly, given that reusable gowns are constructed from higher-quality materials, we explore the potential integration of advanced functionalities using smart textiles as **innovation opportunities** to boost their attractiveness. Complementary to existing research that validates technical feasibility of reuse (McQuerry et al., 2021), this study focusses on the user-fit.

2. Methods

Wearing tests with reusable surgical gowns were organised as a means to evaluate user experiences. Qualitative observations of the staff's behaviour during wearing tests and an evaluation survey were conducted. The tests took place in two Flemish University hospitals. In each hospital the wearing test consisted of one day observation with the hospital's regular disposable surgical gowns (as a benchmark) and four days observation with reusable surgical gowns. A pilot study of one day duration was completed before the official wearing test took place. During the pilot, observations with disposable gowns were conducted. The researchers compiled consent forms and prepared additional information sheets for staff members that had questions about the research and the gown's environmental benefits. In total, 34 surgical procedures were observed over a period of 11 days. An average surgical procedure while observing had a duration of 3 hours and 22 minutes, using on average 4.31 gowns per procedure with 7 staff members in the operation room, of which on average 3.6 in a sterile attire. Wearing tests were performed in the following disciplines: urology, gynaecology, orthopaedic, general, cardio, abdominal, vascular, hepatobiliary, neuro, plastic, gastro, and thoravascular surgery. Different types of procedures were observed: laparo-, gastro-, and, endoscopy, as well as open and robot surgery and small external interventions. Reusable gowns were worn during 8 days, a total of 89 reusable gowns were used over 22 surgical procedures. All reusable gowns were a size medium (150 cm gown length).

2.1. Participant selection

For each day of the observation, one operating room (OR) was selected for the test. The OR was selected by random sample from the rooms in use that day. Staff that was scheduled in the selected OR, participated in the wearing test and received the survey afterwards. The evaluation survey was distributed to all participants of the wearing test ($n = 124$). A total of 78 respondents opened the survey, with 68 completing it in full. Of the respondents, 51.4% ($n = 37$) were female, 47.2% ($n = 34$) were male and 1.4% ($n = 1$) selected 'other'. Respondent ages ranged from 21 to 69 years, with an average age of 35.4 years. The majority of respondents were doctors (52.8%, $n = 38$), followed by nurses (34.7%, $n = 25$), and 12.5% ($n = 9$) reported other roles. The majority of survey respondents (90.3%, $n = 65$) perform tasks that require sterile attire. On days when they wear sterile gowns, respondents spend an average of 5.73 hours ($SD = 2.74$ hours) in sterile attire, typically using 3.24 gowns per person per day ($SD = 1.53$ gowns), with usage ranging from 1 to 8 gowns per day over multiple procedures. This translates to an average wearing time of 1 hour and 46 minutes per gown.

2.2. Data collection

One researcher was present in the OR to observe the staff's behaviour. Notes were taken about general information of the surgery (duration, discipline, employees etc.). **Observation notes** of the staff's behaviour were structured into four interaction-stages: (1) preparation of the OR: includes taking the necessary materials from the storage room before the patient enters the room, (2) donning of the gown: the process from opening the gown when a person is to be dressed fully sterile, (3) wearing gowns during the surgical procedure, and (4) doffing (taking off) and collection of the gowns. To complement the observation notes, **videos** of the donning and doffing process were taken while the researcher asked participants to comment on their recent experiences. After the wearing test, participants received a **survey** evaluating the usability of the tested gown. Questions were asked about their experience at each stage of a surgical procedure, if a stage was evaluated as (very) difficult, the participants could briefly describe the challenges they experienced. Participants could also provide general remarks on overall

usability. The survey's second section focused on improvement opportunities, including a multiple-choice question about healthcare personnel's preferences for additional smart features. The combination of these data collection methods (Figure 1) allowed us to capture both what participants say and what they do. Ethical clearance for the research is granted by the Ethics Committee for the Social Sciences and Humanities of the University of Antwerp (SHW_2022_27_1). All staff members were informed two weeks prior to the wearing test about the research and use instructions of the reusable gowns. All staff members gave their written consent on the day of the wearing test.

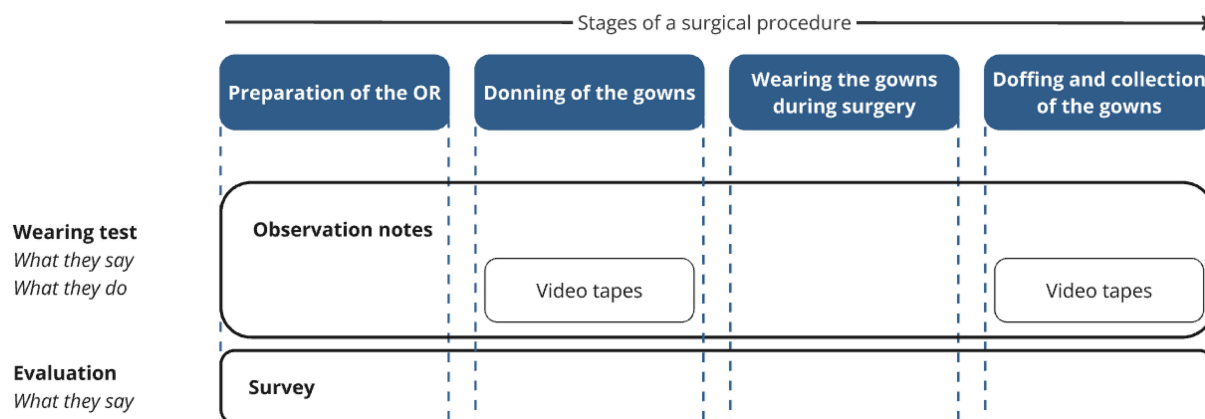


Figure 1. Data collection methods per stage of a surgical procedure

2.3. Data analysis

First, a standard donning and doffing procedure is defined based on the observations. Observation notes were digitalised and transcriptions of the videos were added to the digital observation notes. Thematic analysis (Braun & Clarke, 2013) of the observation notes and the open survey questions was done using NVivo software. Text sections describing deviations from standard procedure were coded. Initial codes were structured following the stages of a surgical procedure and themes were named descriptive according to what the selection is about. Lastly, codes were checked for consistency. Transcription and coding were done by the researcher that carried out the observations to ensure familiarity and understanding of the themes discussed (Thomas, 2006). The coding tree can be viewed in Table 1. For the usability per stage of a surgical procedure and the multiple-choice question about smart features from the survey, frequency and percentage of the answers were recorded.

Table 1. Coding tree for usability of reusable gowns

Code	Description	References
Packaging	Comments that concern the way the gown is packed	14
Paper	Remarks specifically about the two layers of paper packaging	26
Folding method	Comments that deal with the folding method of the gown	72
Donning	Comments made during and which are about putting on the gown	29
Closures neck	Notes addressing the neck closure when putting on the gown.	38
Ribbons inside	Remarks on the ribbons that need to be tied inside the gown	51
Belt card	Remarks on the card for sterile donning attached to the belt	42
Belt	Notes related to the belt at hip level	66
Wearing	Comments made during and which are about wearing the gown.	44
Weight	Notes regarding the weight of the gown	11
Neck opening	Notes about the neck opening when wearing the gown	19
Sleeves and cuffs	Comments that concern the sleeves and/or cuffs of the gown	29
Fitting size	Comments and observations related to gown fitting	19
Fabric and absorption	Notes on the fabric and whether it is absorbent or not	32
Warmth	Comments on the heat feeling while wearing the gown	45
Doffing	Comments made during and which concern taking off the gown	32

(Continued)

Table 1. Continued.

Code	Description	References
Tearing open	Notes on tearing/loosening the gown while taking it off	38
Neck closure	Events and/or comment on opening neck closure	31
Ribbon inside	Events or comments on the closure of the ribbons inside	33
Gloves procedure	Comments that concern (the order of) taking off the gown and gloves	19
Collection	Remarks dealing with gown collection after use	33
Gown appearance	Comments that deal with the look of the gown (colour, waist . . .)	18
Remarks and opinions	Comments or opinions shared by staff on reusability	26
Willingness to reuse	When a person does (not) express willingness towards reusability	12
Reference abroad	When a comparison is made with reusable gown used abroad	5
Reference in the past	When a comparison is made with reusable gown used in the past	23

3. Results

Based on the observations, a **standard procedure** was derived for donning and doffing of the gowns (Figure 2) and the general **gown design features** were recorded (Figure 3).

Disposable gown		Reusable gown	
Donning	Doffing	Donning	Doffing
1. Unpack laminated bag	1. Tear open the bow in the belt	1. Unpack two paper layers	1. Untie the bow in the belt
2. Put hands in sleeve opening of folded gown	2. Loosen/tear neck and ribbon inside	2. Unfold gown downwards	2. Unfasten neck snaps and untie ribbons inside
3. Unfold gown (sideways and down)	3. Remove gown (and gloves)	3. Unfold shoulders sideways	3. Remove gown (and gloves)
4. Push arms through sleeves	4. Compacting	4. Push arms through sleeves	4. Compacting
5. Assistance for closures in the back (hook and loop for neck and ribbons)	5. Throw away	5. Assistance for closures in the back (snaps for neck and ribbons)	5. Collect
6. Put on gloves		6. Put on gloves	
7. Take card, spin around and tie belt in a bow		7. Take card, spin around and tie belt in a bow	

Figure 2. Standard procedures for donning and doffing of a disposable and reusable gown

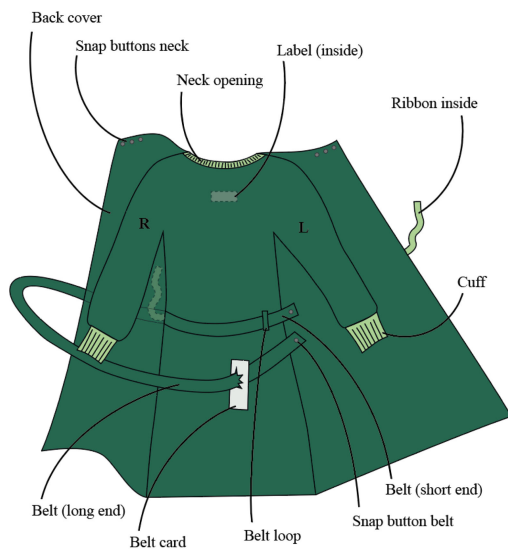


Figure 3. Left: illustration of general gown design features. Right: participants wearing a disposable (blue) and reusable (green) surgical gown

3.1. Usability

Table 2 gives an overview of the evaluated gowns through surveying and their rated difficulty per stage. Not all respondents evaluated each step of a surgical procedure, e.g. circulating nurses do not need to wear a sterile gown, but they prepare the operating room (unpacking gowns) and assist the donning

Table 2. Gown evaluations though surveying (n = 73)

Test gown	Disposable	Reusable
Evaluation by	(n = 15)	(n = 58)
Wearer of a gown	10 (66.7%)	41 (70.7%)
Other staff member in the OR	5 (33.3%)	17 (29.3%)
Difficulty of using the gown - preparation	(n = 11)	(n = 49)
(Very) easy	6 (54.5%)	35 (71.4%)
Neutral	5 (45.5%)	13 (26.5%)
(Very) difficult	0 (0.0%)	1 (2.1%)
Difficulty of using the gown - donning	(n = 10)	(n = 52)
(Very) easy	9 (90.0%)	31 (59.6%)
Neutral	1 (10.0%)	7 (13.5%)
(Very) difficult	0 (0.0%)	14 (26.9%)
Difficulty of using the gown - wearing	(n = 8)	(n = 41)
(Very) easy	4 (50.0%)	32 (78.0%)
Neutral	4 (50.0%)	9 (22.0%)
(Very) difficult	0 (0.0%)	0 (0.0%)
Difficulty of using the gown - doffing and collection	(n = 8)	(n = 46)
(Very) easy	7 (87.5%)	29 (63.0%)
Neutral	1 (12.5%)	9 (19.6%)
(Very) difficult	0 (0.0%)	8 (17.4%)

procedure. The observation notes and video transcriptions provided a rich dataset, based on which we report aspects that deviated from this standard procedure to assess usability of reusable surgical gowns. We describe usability according to each stage of a surgical procedure.

3.1.1. Preparation

The reusable gowns are wrapped with two layers of paper (blue and white) and sealed with stickers. When opening the **packaging** (14 references to this) for the first time, participants handle it cautiously. They often experience some confusion about how to properly open it, leading to uncertainties:

“Is this still sterile if she would also open the white [paper] now, or not?”

Participants noted the **paper** (26 references to this) felt stiff, and the tightly packed layers often got stuck behind the corners of the folded gown. During unwrapping, two participants accidentally tore the blue paper, exposing the white layer and compromising the first sterile barrier. The **folding method** (72) of the gown led to considerable number of comments. While some participants understood the folding method right away, most needed more time or instructions before correctly unfolding. As opposed to the disposable gowns, participants cannot immediately slide their hands into the armholes of the gown and had to search for the sleeves while holding the gown open:

“I personally find it a bit tricky that you can’t put your arms in directly, now you have to spend time searching for the armholes”

This also complicates the way a surgical gown is handed over to a colleague. The folding method was described as difficult and unclear, although participants also mention that *“It’s a matter of developing a habit”*. Participants who had already unfolded the gown once, said it was easier the second time:

“I found that difficult because . . . you have to grab it. Partly that’s definitely a habit, but you’re just afraid to touch the outside instead of the inside. I didn’t find it very convenient that you had to do that first . . . I found the folding method difficult”

3.1.2. Donning

In general, the procedure for donning (29) reusable gowns is similar to that of disposables. The most common difficulty is finding the armholes and putting the hands through the sleeves. Sometimes the circulation nurses had to assist with gown adjustments such as pulling up the sleeves (along the inside), closing the gown at the back or properly aligning the bottom. With practice, participants found donning

the gown easier. Uncertainties arose regarding fastening the **snaps at the neck** (38), specifically whether to fasten one, several or all of them, sometimes prompting them to seek advice from the researcher or feedback from the wearer. Participants complained about the tightness of the neck opening:

“At my neck, can that be looser? Because I have the feeling I’m being hanged”

The circulation nurse often struggles to locate the **ribbon inside** (51), as it may be hidden along the sleeve or positioned too far forward in the gown. Feedback is frequently requested/given on the tightness of the closure. Issues with the **belt card** (42) were also noted: it often is not positioned near the end of the belt, causing the tip to bounce back to the circulating nurse’s hand and make the belt unsterile. The card is often folded upon unpacking, as a result participants have to straighten it before use. A thicker card is suggested. Moreover, they propose to make the cards wider and to add lines for making notes. This is the case with disposable gown, cards are used to note things down quickly:

“If you take one of those cards [shows card from the disposable gowns], those are better and are also good to write on, with lines for notes”

The most notable observation regarding the **belt** (66) of the reusable gown, is that one has to spend some time searching for how to detach the belt from the gown. It is additionally noted that the snap button is different from the fasteners they were familiar with:

“You can’t just grab it [the belt end], you have to look at it to release the button”

Additionally, it was also not immediately clear to everyone how the gown should be closed: “*Buttons or knots?*”. Several comments were made about the belt design, including its position being too high or too far back, and its length being excessive.

3.1.3. Wearing during operation

Wearing the reusable gown (44) is described as generally comfortable. There are several circumstances affecting wearing comfort, such as standing or sitting positions, wearing a lead apron for radiation protection, face shields, and light glasses with cables tucked under the gown. Participants said that it is important that gowns are **lightweight**. While reusable gowns are heavier, they are not considered too heavy or overly distracting. Participants feel as if the gown is **tight around their neck**, this can feel suffocating. Some pull the gown forward to avoid this feeling, one even hung a clamp on her gown as a counterweight. For the sleeves and cuffs (29), most found the sleeve length adequate, though smaller participants noted the sleeves were too long. One participant noted the sleeves were too short, causing the gloves to slide off the cuff and compromise sterility, which is especially relevant for larger individuals. **Cuffs** are usually worn over the palm or wrist. The fabric cuff over the wrist helps against sweat, but can also feel too tight. Participants mentioned that the cuffs felt “*different*”, thicker, stiffer, and slightly itched. Some participants had to pull up their gloves, as the fabric of the gown is said to slide more. Only one gown **size** (29) was tested (medium). For larger individuals, the gowns were long enough, but their back remained slightly open due to broad shoulders. For some shorter individuals, gowns were too long. Regarding fabric and absorption (32), participants noted the importance of **breathability**, especially for long surgeries. The reusable gown’s material was described as plastic-like, resembling “*tent fabric*” or a raincoat, with similar sounds, leading some to anticipate sweating while wearing it. Others found the fabric comfortable or just “*different*” or “*smoother*”:

Researcher: “Is it [the gown] different?”, nurse: “Yes, a bit . . . yeah I don’t know, just normal actually. It feels more like a garment rather than a gown”

It is crucial that the gown is impermeable to avoid getting dirty and cold. Some surgeons and nurses dry or wipe their hands on their gowns, but they note that **reusable gowns absorb less**. One participant puts abdominal compresses in the gown’s belt to wipe hands during surgery. Another participant had blood indeed sliding and dripping off his gown, all the way down into his shoes. People stressed the importance of **warmth** (45) for comfort. Overall, participants found the warmth sensation good. There is concern that it can be too hot when the surgery is long. Some participants did feel warm, one of whom was at the table with a lead apron on and others in a warm room. On the other hand, participants also said the fabric feels cooler:

Nurse: “When you put it [the gown] on, it’s cold [shakes shoulders up and down, laughter in the room]”, someone: “Really?”, surgeon at the table: “I feel cooler than I usually have in an operating room”, someone: “That’s good”, nurse: “Yes, I thought they were going to be warm, but it’s not”, researcher: “Is it better, or are you too cold now?”, nurse: “No I prefer it cooler”

3.1.4. Doffing and collection

Some participants manage to take off the gowns (32) themselves, but some found it difficult e.g. too long spent untangling the ribbons. Other participants needed help (for ribbons and snaps) to take off the gown or asked for instructions before starting. Overall, loosening the gown’s closures **took more time** than ripping it off. Participants commented that they are used to **tearing off the disposable gowns** (38), but that once they are used to the actions, untying works as well. Some did express a preference to be able to tear it off. Many participants do not dare to pull on the reusable gown. The **closure in the neck** (31) can be pulled open with a tearing gesture, but this does not always work. Some participants grab behind their neck to open the snap buttons. Sometimes the gloves are removed first. In other cases, a colleague comes to help open the snaps. Usually, untying the **ribbons inside** (33) requires help, although some can do it themselves. Participants find it difficult to untie the ribbons and it evokes unpleasant feelings for some. Possible alternatives are proposed like snaps or another tie technique:

Surgeon: “I’ll try if I can take it off myself . . . [grabs behind back and tries to find the bow inside] . . . not so . . . [brings knotted ribbons along right front and finds the bow] . . . so that [the bow closure inside] has to change, because that’s hateful . . .”

According to the procedure, the **gloves** (19) should be taken off after the gown. Gloves are sometimes taken off simultaneously with the gown if they are very dirty, gloves then remain in the sleeves of the gown. But with reusable gowns, the gloves and gown must be collected separately. Sometimes they both will end up in the laundry bag, something the laundry service needs to watch out for. The gown is opened with gloves if they are still clean, but sometimes also with bloody gloves on. Some participants took off their gloves before opening the gown. Participants roll or stuff the gown into a ball or fold it before **collecting** (33). For some participants, it was not clear where to collect the reusable gowns. Some were also commenting about an extra collection bag in the room.

3.1.5. General comments and opinions

About the **gown appearance** (18), it is noted that the belt accentuates their waist. The different colour is noted and also that the look is different as it is more like a coat. Some call it a pretty or a modern gown. One participant finds the colour confusing because it is no longer immediately clear who is sterile and who is not. There were participants that explicitly expressed their satisfaction with the reusable gown, others express a sceptical attitude or are neutral about it. Some shared their doubts about the environmental advantage of reusable gowns. **Willingness to reuse** (12) over the participants is divided. One nurse who initially did not feel like trying the gowns, wears a disposable gown during the first surgery. During the next surgery, she said she would like to join in with reusable gowns. Participants made spontaneous references to **experiences from the past** (23), some were neutral, others positive, or negative. Also **references from abroad** (5) were made, including countries like Uganda, Benin, Cambodia, Korea and the Netherlands.

3.2. Improvement and innovation opportunities

Respondents in the survey indicated which additional smart features they consider would improve (the comfort of) a surgical gown. Answers to the multiple-choice question are displayed in Table 3.

Table 3. Opportunities as indicated by the survey respondents (n = 68)

That a reusable surgical gown . . .	Count
enables sweat drainage.	42 (61.8%)
is recycled into a new reusable surgical gown at the end of its use cycles.	36 (52.9%)
has a cooling function for the user.	31 (45.6%)
is made of recycled material derived from discarded reusable surgical gown.	30 (44.1%)
packed along in custom procedure trays.	25 (36.8%)
	(Continued)

Table 3. Continued.

That a reusable surgical gown . . .	Count
has a monitoring system that indicates when the gown needs replacing (e.g. bacterial growth, failing water resistance . . .)	25 (36.8%)
includes an additional communication element that verifies sterility.	16 (23.5%)
can be repaired invisibly (e.g. sealing a hole).	14 (20.6%)
has a heating function for the user.	10 (14.7%)
includes a smart measurement and warning system for radiation exposure.	8 (11.8%)
can be linked to previous interventions to trace in case of calamities.	7 (10.3%)
can automatically be registered with the products used per procedure (e.g. by using a chip).	7 (10.3%)
can monitor the user (stress level, heart rate, sweat production . . .).	2 (2.9%)

4. Discussion

4.1. Implications for gown design to enhance usability and trust

Firstly, the **packaging and presentation** of surgical gowns are vital for maintaining sterility. Although reusable gowns use different packaging, the envelope wrapping technique was recognisable. Two participants broke the first sterile barrier when tearing the blue paper, but this was easily resolved by unwrapping the second layer, highlighting the benefit of double-wrapped packaging. The folding method of the reusable gowns was criticized for being time-consuming and requiring extra instructions. A common suggestion was to make the armholes for the sleeves directly accessible in the folded gown to speed up donning and facilitate sterile handover. Secondly, the **design of surgical gowns** is critical for ensuring comfort and sterility. Some participants felt that the neck opening was too tight, indicating a preference for a wider neck opening. Although the test used only one size (medium), it is noted that gown sleeves should be long enough to tuck cuffs under the gloves for a sterile barrier. Participants also used their gowns to wipe their hands but found that reusable gowns absorbed less effectively. Additionally, blood or fluid leakage from tubes could run down the gown into shoes, suggesting the need for an absorption strip at bottom of the gown. Attention should be given to the belt card, as participants noted during the donning procedure that the belt end through the card was too long, risking sterility if it bounced back to the nurse's hand. Unlike disposable gowns, where the unsterile belt end can be cut off, reusable gowns require unpacking a new gown. Suggestions include a thicker, wider belt card with writing lines. Doffing reusable gowns takes more time as they need to be untied rather than pulled off. 'Tearable' closures like snaps or another tie technique could be considered, however, snaps have drawbacks such as being difficult to replace and having a short life span (Syed et al., 2022). The **material selection for reusable gowns** must balance comfort, heat sensation, permeability and breathability for sweat vaporising (Rutala & Weber, 2001). Feedback on wearing comfort varied, with some participants finding the gowns cooler, and others too warm. To better understand gown comfort, tests in controlled environments should be consulted. According to Georgievska et al. (2024), reusable gowns exhibit better heat transfer and higher water vapour permeability compared to disposable gowns. This suggests that reusable gowns may offer improved comfort in terms of temperature regulation and moisture management.

4.2. Implications for developing innovation strategies

Like every **adoption process**, reusable surgical gowns face resistance to change (Bovey & Hede, 2001). Developing new habits for the donning, and doffing procedures can address many of the issues raised during testing. Supporting habit change can be achieved through a combination of interventions, such as educational communication about the environmental impact of healthcare waste to increase implementation intentions, and improving usability to make the new behaviour easier to perform (Verplanken & Wood, 2006). Extra functionalities for surgical gowns, such as **thermal (heat) regulation**, sweat drainage, and a cooling or heating function are seen as improvements. A smart **gown monitoring system** to indicate when a gown needs replacing due to e.g. bacterial growth or failing water resistance also received attention. Respondents showed interest in **improved circularity** of the gowns as about half of them indicated to be interested in recycling a used gown into a new gown and to wear gowns that are made out of recycled material derived from discarded reusable surgical gowns. Lastly, including gowns in custom procedure trays was considered practical and time-saving.

4.3. Implications for the value-chain

Although, value-chain partners acknowledge the importance of optimised usability, changes to the current gown design can disrupt well-established **reprocessing protocols** (e.g. washing, folding, storage) (Syed et al., 2022). Similarly, when incorporating extra functionalities for reusable garments, the washability should be considered. Conductive yarns or electronic components can be sensitive to mechanical or chemical cleaning. Solutions such as modular design enable separation of electronic components (e.g. a snap button or zipper), or the selection of the appropriate reprocessing protocol (temperature, cleaning products or auxiliary reprocessing tools) can prevent damage (Rotzler & Schneider-Ramelow, 2021). **Clear guidance and instructions** should be provided and shared among value-chain partners, as they work together to ensure a functional and clean reusable product. Additionally, partners should also be clear about the **ownership of the product** (Hellström & Johansson, 2010; Mahmoudi & Parviziomran, 2020). The owner or buyer of the product is the partner that can define design requirements and additional functionalities for the product. For purchasing managers, when evaluating new products, items are ideally demonstrated or tested by staff, feedback is collected, and staff may advocate for products they believe could reduce their workload. A balance between user needs, healthcare expenses and industry profits remains the core challenge.

5. Conclusions

To tackle resource depletion and incineration of waste, this research supports the adoption of reusable surgical gown in healthcare. Staff's interactions during a wearing test were investigated, and an evaluation of gown usability with the potential integration of advanced functionalities was conducted. The wearing test with reusable gowns uncovered **design recommendations** that could improve usability for the user. From most coded to less coded: a folding method that allows direct access to the armholes, 'tearable' closures of the gown, a wider neck opening, more sturdy belt card with improved attachment to the belt, a lower belt position, and absorbing fabric or an absorbing strip/area. **Innovation opportunities** lay in the incorporation of smart textiles that allows thermal regulation of the gown. This can either be a cooling or heating function, or sweat drainage. The design of the gown is defined by the value-chain partner that has ownership of the gowns. Future research into reuse models and ownership can foster design iterations to improve usability, as well as the collection of the gowns.

Acknowledgement

The authors thank CleanLease B.V. for leasing and transporting the reusable gowns, and the University Hospitals of Antwerp and Ghent for facilitating observations in the operating theatre. Appreciation is extended to all study participants. Financial support from the Flanders Innovation & Entrepreneurship, (TETRA funds, HBC.2021.1025), Belgium and the University of Antwerp (Bijzonder Onderzoeksfonds, 44104) is gratefully acknowledged.

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