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Evidence-Based Design in an Intensive Care Unit: End-User Perceptions

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by

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Abstract

The objective of this qualitative case study was to describe end-user impressions about the design of the new Foothills Medical Centre intensive care unit in Calgary, Canada. I performed thirty-nine interviews with unit workers and family members. twenty-four in the early phase and fifteen in the late phase. Four themes and eleven sub-themes were identified: atmosphere (abundant natural light and low noise levels), physical spaces (single occupancy rooms, rooms clustered into clinical pods, medication rooms, and tradeoffs of larger spaces), family participation in care (family support areas and social networks), and equipment (usability, storage, and providers' connectivity). End-users considered a pleasant atmosphere, attending to the tradeoffs of space and size, designing family support areas to encourage family participation in care, and updating patient care policies and staffing to reflect the new physical space as important elements when building intensive care units.

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List of Symbols and Abbreviations

ICU: Intensive Care Unit

FMC-ICU: Foothills Medical Centre Intensive Care Unit

SCCM: Society of Critical Care Medicine

POE: Post-occupancy evaluation

IQR: Inter quartile range

n: Number of participant's comments on a theme

MF: Mauricio Beller Ferri

AH: Alexandra Harris

DAZ: David A Zygun

HTF: Henry Thomas Stelfox

Chapter I: Introduction

The governments of the United States and Canada launched structured programs to fund construction and renovation of healthcare facilities shortly after World War II. In the United States, the Hospital Survey and Construction Act (Hill-Burton Act) established a partnership between federal and state administration to address the shortage of healthcare facilities and to stimulate the development of design standards. This program helped more than 7000 hospitals before it was terminated in 1975.[1,2] Similarly, in Canada, the Dominion-Provincial partnership intended to offer financial support for planning and building of new healthcare facilities, culminating with the Hospital Construction Grants Program instituted by the federal government in 1948.[3] In the decade following the institution of the Hospital Construction Grants Program, an average of thirty new hospitals were constructed every year, increasing the number of facilities by a third and the number of available hospital beds by two-thirds.[3] More recently, the healthcare facility construction industry is growing exponentially to accommodate greater demand for access and quality of health services and the ageing infrastructure.[2,4]

Expanding health services and design-focused research in conjunction with a growing emphasis on quality improvement in healthcare delivery has contributed to the emergence of evidence-based design.[4,5,6] Evidence–based design is the incorporation of the best available knowledge from research and practice into the decision making process about design and layout elements (i.e., healthcare physical environment).[6] When applied to the healthcare industry, this novel approach extends beyond minimum construction

standards and aims to recommend facility design features that improve clinical performance and create "healing environments".[4,6,7]

Evidence-based design may be particularly relevant for intensive care units (ICU) in which patients have life-threatening conditions and the model of care is based on multidisciplinary teamwork. Building codes and guidelines recommending minimum standards for materials and ICU layout comprise a heavily regulated industry. In this milieu, ICU leaders are constantly challenged to increase quality, reliability, and safety of service delivery.[8,9,10] The characteristics of the ICU built environment may impact service flow, affecting the social behavior of end-users, hindering or facilitating processes of care,[11] and, potentially, shaping the interaction of patients, families, and providers.[4,9,2,12]

Objective

The objective of this study was to describe end-user impressions and experiences with the design of the new Foothills Medical Centre intensive care unit (FMC-ICU) in Calgary, Canada. The study ICU was constructed using evidence-based design and received the Society of Critical Care Medicine (SCCM) ICU Design Citation award in 2012.[13,14,15] Clinicians and design experts collaborated in the planning process that started with defining their vision of the ideal facility and developing local guidelines which incorporated state-of-the-art technology and functionality in a pleasant environment for end-users. Subsequently, the planning team used life-size simulation to determine room configuration and equipment disposition.[15] The new FMC-ICU incorporated design features such as

single-occupancy rooms, patient care rooms clustered into clinical pods, and dedicated family support areas.[4,6] I took advantage of the opening of the FMC-ICU to determine end-user impressions and experiences with the evidence-based design features.

Chapter II: Literature Review

The existing literature suggests a relationship between the built environment of healthcare facilities and important aspects of their functioning.[4] Despite very few conclusive studies about the positive or negative impact of design elements in ICUs, most clinicians and ICU administrators believe that mitigating the artificial environment, sometimes called hostile, is important to improve the quality of care for the critically ill.[4,5,6,16,17]

Over 40 years ago, a landmark study about the effects of windowless ICUs on the incidence of postoperative delirium initiated the interest in the potential impact of the built environment on health outcomes.[18] Since the original findings, the impact of outside deprivation (i.e, lack of access to natural light and views of nature) has been confirmed and refuted in subsequent studies in different patient populations.[2,19,20,21,22] This example shows how the evidence for design interventions evolved in light of growing healthcare facilities construction. Similar experiences have characterized research about noise levels,[23] single rooms and bedside layout,[24,25,26,27] and equipment usability.[17,28] A recent publication described the trends in design of award-winning ICUs of the "SCCM Design Citation Award " over 17 years,[29] highlighting best-practices in design that were present in newly built facilities eligible for the prestigious competition: larger size, private rooms, family zones, ceiling mounted equipment, proximity to support areas in the hospital, increase in administrative space, access to nature. The authors could not identify any specific trend in unit geometry and circulation.[29] The reality of healthcare facility construction clearly demonstrates that evidence-based design, in accordance to one of the

most accepted definitions, incorporates the best available evidence from research and practice into design decision-making,[6] and when little scientific evidence has been generated in a specific topic, trends and architectural practice help shape the choice of healthcare facility design elements.[29]

Insofar as the body of design research is recent, the demand for better service delivery increases exponentially, and the pressure for buildings that improve clinical outcomes grows (healing environments), increasing the interest in the science and art of building performance evaluation. In fact, the need for systematic evaluation has led to a multitude of programs and examples of how to assess the performance of healthcare facilities.[5,7] The traditional post-occupancy evaluations (POE) were an important source of learning and provided feedback on the performance of specific design elements and the practicalities of the occupation process. This approach did not enable the depth and comprehensiveness of information required to assess the impact of the building design on clinical and organizational outcomes.[4,5,30,31] However, POEs have been successfully implemented in the ICU environment,[5,32-35] and continue to be the most common example of applied research in healthcare design.[4,5,36] Recently, many authors expanded the scope of healthcare facilities POE to encompass both environmental and operational aspects of the building life cycle, with particular emphasis on performance measurement and its impact in health outcomes.[4,5]

Chapter III: Methods

Approach

I chose to approach this research question with a qualitative lens given the complex nature of the design intervention that motivated this study.[37,38] A new ICU building may affect end-users through uncertain pathways insofar as there are multiple components with heterogeneous mechanisms of action and contexts. In this setting, to fulfill my research objective mandate and describe end-user impressions about the new FMC-ICU design, I decided to keep focus on learning and exploring the meaning that participants had of this event as experienced by themselves in their natural context. Only the methodical collection, organization, and analysis of textual data derived from interacting with end-users through conversation would allow me to grasp their multiple perspectives and diverse views.[38] This approach relied on the paradigm of a social construction of reality (social constructivism interpretative framework), highlighting the dependence of truth on individual perspectives.[38,39] Accordingly, I elected a descriptive qualitative case study design because of three specific attributes of my research project. First, the event occurred in contemporary setting to the investigation. Second, it was of paramount importance to consider the context in which the event occurred to understand how and why it impacted end-users. Third, the boundaries between context and event were not clear,[40,41] since any given impact on end-users impression (case) would have happened within the FMC-ICU, making it impossible to separate event and context.[41]

In order to maintain the study within a reasonable scope, Yin and Stake suggested that

researchers placed case boundaries as clear as possible. I elected case boundaries by time and place.[38,40,41,42] Thus, the case was defined as the description and understanding of early and late end-user perceptions about the design of the new FMC-ICU.

I conducted two phases of individual, semistructured, in-depth interviews with the end-users of the FMC-ICU. Individual interviews allowed participants to tell their stories and describe their views in detail, including potentially sensitive issues related to negative aspects of the ICU design.[38,43] The plan to perform two phases of data collection was to account for both the "settling–in" period, when problems are most frequent, and the "halo effect", associated with moving to a new facility.[5,6,7] In addition, complex interventions often have dynamic features with changing impact over time.[37] Early phase interviews were administered two to three months after the facility opened and late phase interviews twelve to fifteen months after it opened. The Conjoint Health Research Ethics Board at the University of Calgary approved the study protocol (E-24609). I obtained informed consent from all study participants prior to enrollment.

Interview Guide

I generated an interview guide using a focused literature review, examination of local guidelines for ICU design, and individual, in-depth interviews with four key informants who served on the local design committee (two physician leaders, one administrator, and the department chief registered nurse). The aim of these interviews was

to gain insight into the committee's design intentions and understanding about the knowledge base of benefit for each element included in the final project. The interviews were audiotaped, transcribed verbatim, and analyzed with the same methodology described below for the study participants. The resulting interview guide (see appendix B) consisted of open-ended questions encouraging participants to freely engage in informally toned conversation and reflect on their impressions and experiences about the new FMC-ICU. Probing points were used to investigate further specific evidence-based design features that were discussed during the interview. The interview guide was pilot tested with three local healthcare providers that would have been eligible for the study and improved based on their feedback.

Sampling strategy

I utilized a non-probability sampling strategy (maximum variation purposeful sampling) to obtain a wide range of perspectives representing the typical diversity of end-users' groups experiencing the new ICU facility. I chose a maximum variation purposeful strategy to enroll exclusively individuals that could contribute to my understanding of the case, maximizing the different perspectives about the study phenomenon.[38] I included healthcare providers, support staff and patient family members. The study was locally publicized with electronic messages to inform end-users of the purpose, time, and location of the interviews. Recruitment occurred during typical working shifts to facilitate participation. The decision to enroll was voluntary and the interview could be immediately terminated at the participant's request.

Analysis

I analyzed verbatim transcripts of individual, semi-structured, in-depth audiotaped interviews. I used a traditional qualitative interpretative framework of social constructivism with an iterative and reflexive process to understand the complexity of the perceptions.[38,40,42] This involved multiple reviews of the transcripts, highlighting ideas, identifying key concepts as codes, using constant comparison to refine and modify the codes, grouping broad topics into themes through careful reading and re-reading of the data. Initially, I coded and analyzed six transcripts and concomitantly developed a qualitative codebook to define, code, and synthesize the core ideas expressed by the participants into themes.[38] Subsequently, I divided themes into sub-themes that described the findings in more detail. The members of thesis supervisory committee reviewed and revised the coding scheme, which I applied to all transcripts with minor adjustments in the following iterations. The same process was utilized for the analysis of the key informant's, early, and late phase interviews.

Theoretical framework

This research project aimed to describe the impressions and perceptions of end-users about design elements spread across all functional zones of new FMC-ICU (i.e., physical areas housing a set of interrelated functions).[4] Design and layout interventions were predominantly structural elements (e.g., facilities, equipment, and material

resources) that had potential implications in processes of care (activities that constitute healthcare) and outcomes (meaningful changes in status). As a final step in the data analysis, I developed a theoretical framework to classify and visualize end-user perceptions merging the three domains of Donabedian conceptual model for quality of healthcare delivery (structure, process, and outcome) and the components of the ICU functional zones framework proposed by the 2012 SCCM Guidelines for Intensive Care Unit Design (patient care zone, clinical support zone, unit support zone, and family support zone).[4,44,45]

Chapter IV: Results

I interviewed thirty-nine end-users of the FMC-ICU, twenty-four in the early phase and fifteen in the late phase. Table 1 describes participants' characteristics grouped by study phase. My analysis produced four themes (atmosphere, physical spaces, family participation in care, and equipment) and eleven sub-themes (Table 2).

Atmosphere

All participants mentioned a brand new ICU with a pleasant atmosphere as a major positive impact in both phases. The effects of a pleasant atmosphere were apparent for patient families and providers, who both reported that they resulted in calmer families more willing to interact with the provider team. The most impactful elements of atmosphere were natural light and lower noise levels.

"Well, number one, it's brand new (…) So that's very impressive. The room that my husband is in is wonderful (…) size-wise, beautiful view."

Abundant natural light. It was the most frequent component of a pleasant atmosphere described. The majority of participants highlighted the perceived benefits of a brighter facility with more windows. Three noted that the ICU was bright during the day and adequately dark during the night, creating conditions for day/night cycle. The related construct "views of nature" was identified as having a positive impact on the mood and morale of end-users.

"It's bright, because so much of our work is dark. You know, it's heavy, it's emotion-laden, it's fearful, it's stressful, there's a lot of death, there's loss. You know, it's depressing. So it is really important to have a bright, colourful environment"

"At night it's darker I think, whereas before we had [artificial] skylights and … it wasn't always as dark."

Lower noise levels. Participants associated lower noise levels with better concentration and ability to complete clinical tasks, such as rounding, with fewer interruptions (n=20). They perceived lower noise levels to be a sign of respect to patients

and family members. As a negative point, the unit was perceived as noisy during handover between work shifts. Providers suggested the cause was the bedside design with decentralized nursing stations and two teams of nurses sharing the same workspace.

"The most significant change that I have seen is the fact that the unit is very quiet. You can round in an ambiance that allows you to concentrate on -- on your work. You no longer have the multiple distractions that we used to have in the -- in the previous unit (…) It was so noisy and so very many interruptions that oftentimes I was concerned with my ability to -- to maintain my -- my concentration"

Physical spaces

End-users identified three physical spaces as important: single-occupancy rooms, rooms clustered into clinical pods, and medication rooms. Many end-users made both positive and negative comments about overall unit size and space. Some identified tradeoffs of size and space, including the challenge of larger physical spaces resulting in greater distances between patients, patient families and providers.

Single-occupancy rooms. Sixty-nine comments described positive aspects of single-occupancy rooms: privacy for patients and families (n=20), confidentiality during clinical encounters (n=25), room to accommodate providers during routine and emergency care, and presence of family members at the bedside (n=18). Six participants indicated that

single-occupancy rooms allowed for better infection prevention and control practices. Three family members commented that the care provided in single-occupancy rooms was perceived as more individualized.

" There's just the space to move, there's space to get equipment in and out, there's space to get people in and out. It just makes it easier to actually do your job 'cause there's physically the space to do it"

In the early phase, participants mentioned safety concerns, including increased distance from patients, lack of visual contact, and perceived difficulty hearing alarms (n=12), feeling isolated from other providers (n=8), and concerns about calling for help from inside the room (n=5). In the late phase, nurses did not mention isolation but still commented on concerns about calling for help from inside the room (n=3) and the distance from the patients (n=2).

" I would say the four walls around us kind of hinders maybe sometimes getting help. Like there used to be curtains between us, and you could see the feet shuffling underneath and you'd say hey you, you know, I need help. Now it's not quite as easy to just call out for help"

"… before you could just open the curtains, you could see six patients, so you could help

whoever was crashing, here you can't because you just can't see more than two patients at a time."

Rooms clustered into clinical pods. There were seventy-five comments on negative aspects of patient rooms clustered into clinical pods. The comments suggested that the clinical pods were excessively spread-out, which hindered social interaction and camaraderie among providers (n=11) and reduced visual contact between providers, "hampering" situational awareness (n=20). Although participants thought it was more difficult to find people within the unit, this was not perceived to impact informal professional support networks (e.g., asking someone else for clinical advice) (n=9). Nine participants indicated the layout was a barrier to diverting providers to busier areas within the ICU when help was needed. Physicians noted increased walking distances made it more physically demanding to look after patients in different pods. Nurses commented that cross coverage of patients was more difficult with larger physical spaces, and that this challenge had not been anticipated prior to opening the new ICU (n=6).

"*Again, the physical plant is so spread out; when we have to cover you don't know what's going on in the units (clinical pods). And for us, that's tough when you're on call, right? Like if somebody's really sick, they have to be able to get a hold of you, you have to get there. So that's one thing."*

" We used to always be so close together that we were all tight in the same place, which led to a more social atmosphere, I found. Sometimes you feel—I don't want to say isolated, but sometimes you feel like everyone's very far away and there's not that camaraderie and immediately social aspect."

There was no mention of any positive aspects of rooms clustered into clinical pods in the early phase. In the late phase, four participants mentioned that this arrangement facilitated identification of the ICU team by family members and consultants. They also commented that separate clinical pods allowed end-users to avoid exposure to events occurring in other areas of the ICU (e.g., noise and activity associated with movement of patients in and out of the ICU or stress of patient resuscitation).

"…I like the separate pod idea. Because if you were in the open unit, when it was busy in one side, it felt like the whole unit was busy, right? And it would be just wearing on you."

Medication rooms. Nurses mentioned the impact of a dedicated and distinct medication room twenty times. The size allowed multiple providers to use it simultaneously at peak medication hours (n=9). Lower noise levels were reported to lead to perceptions of less distraction during medication preparation, fewer errors and increased safety (n=2). The main negative point was the need for nurses to have their

patients monitored by a colleague while using the medication room because they could not hear alarms from the room (n=4).

" I guess it's nice that it's divided up—three, one in each pod. It's not a mad rush and first thing in the morning, you're not fighting. So I guess that's something."

"If I have to go and get a medication, it's hard to hear your patient, right? If there's an alarm or something, … and sometimes if you have a really sick patient, it's a little bit sketchy running to get a med."

Tradeoffs of larger spaces. All participants indicated that the positive aspects of more space outweighed the negative. End-users suggested that more space facilitated the presence of family members at the bedside. They also felt that more contact with the provider team reassured families about the quality of care provided and improved the perception of coordinated teamwork. Providers commented that larger hallways and more space at the bedside facilitated seamless teamwork activities including fewer interruptions during multidisciplinary clinical rounds. Nurses mentioned that the implementation of a wireless provider-to-provider communication system (n=5) was perceived as good solution for communication difficulties created by a larger unit. Providers felt subsequent improvements in the emergency response system within the ICU (i.e., providers could

trigger a local code call from inside the room with the touch of one button) increased safety in a larger space (n=3). In addition, end-users commented that local policy and guidelines were outdated and limited the perception of improvement brought by larger spaces (e.g., policies restricting the number of visitors at the bedside to two).

Family participation in care

Family support areas. End-users identified the location of family areas in relation to other hospital amenities (n=19) as important. Family support areas that were close, but physically separated from the patient care area, were identified as a positive attribute by end-users. Participants highlighted positive (n=6) and negative (n=3) aspects of the overall size family support areas and rooms. They suggested larger areas were important to accommodate larger groups of visitors in a comfortable way. They indicated larger areas helped a diverse group of visitors to simultaneously use the space. In contrast, one provider mentioned that large areas felt cold and impersonal. Conversely, smaller rooms were more intimate, but visitors "camped" in them, limiting access for others.

"So it would be nice if we had, you know, a big room, a big waiting room with some small rooms that could be used for privacy for some people, right, within that big unit, that big… big waiting room. So it seems a bit cold in there."

" But I actually think that they are very much appreciated by families and you're making a statement, which is (…) you are thinking about not just the patients, not just the staff, but the families that often have a 24-hour presence as long as people are in the ICU"

Social networks. End-users suggested that the family support area location was crucial to developing informal social networks among visitors, facilitating way-finding and transitions of care out of the ICU. A healthcare provider questioned if more flexible rooms, with smaller and more private areas, could enhance interactions between families of different patients, facilitate sharing of experiences, and help create family networks. Two family members appreciated the availability of computers with internet access and free public telephones, which enabled communication with relatives and friends and fomented social networks and interactions.

"And it helps to talk to people, I think (…) Most people want to talk about their situation, right?"

Equipment

Usability. Participants commented on equipment usability seventeen times. In the early phase, providers identified negative aspects of new equipment usability such as problems getting used to the dual pendant-mounted system, with medical gases and power

outlets suspended from the ceiling (n=4), and malfunctioning automatic doors impeding rapid access between units (n=4). However, in the late phase, they indicated that having innovative equipment (e.g., ability to display patient monitor information on the room television screen) was perceived as positive and helpful to patient care (n= 9).

"The arms are very frustrating because before you could decide where your ventilator was, where your IV pumps and if you did a bronch, I would pull my IV pumps to the foot of the bed so it would be out of everyone's way."

Storage. Participants indicated that the storage of supplies and equipment needed to be identical in each clinical pod so that providers knew where to find them (n=5). Two nurses indicated that the presence of supplies within patient rooms facilitated workflow.

Provider connectivity. Providers perceived increased computer availability as a positive feature to access information and document clinical care (n=19). In contrast, two physicians suggested it could be distracting from clinical tasks.

"Also the increased availability of lots of computers. So you're not fighting for space or a computer to do recording."

Chapter V: Discussion

My analysis provides an opportunity to understand how evidence-based design

impacts the impressions and experiences of ICU end-users. Abundant natural light and low noise levels improved the perception of a pleasant atmosphere. Participants emphasized tradeoffs of size and space, identifying safety concerns of increased distance between end-users. Physical and functional characteristics of family support areas influenced the reported integration of family members in patient care. Unit polices needed adjustment to reflect the new facility design.

Despite a growing body of evidence, conflicting study results have not allowed conclusive identification of essential design features to transform ICUs into "healing environments".[2,4,21,46] However, the SCCM ICU design guidelines recommended features that were identified as important in our study including natural light, low noise levels, single occupancy-rooms, unit arrangement with rooms clustered into clinical pods, and family support areas.[4]

The guidelines suggested natural light is essential and recommended at least one window per patient bed area.[4] This is supported by the findings in this study since abundant natural light was the most frequently identified feature for a pleasant atmosphere. However, a recent secondary analysis of a large cohort study in patients with brain injury did not show improvement in patient outcomes with the presence of windows in ICU rooms.[21]

End-users in this study described benefits of lower noise levels. In addition to facilitating patient sleep, which has been described elsewhere,[27,29,47,48] they suggested it improved concentration and task completion (e.g., clinical rounds) and thought quietness was a sign of respect for the families. In agreement with previous studies, one provider

commented that family members appeared calmer and more willing to engage with the team as a result of a quieter atmosphere.[2,46]

The latest SCCM guidelines for the management of pain, agitation, and delirium in adult patients recommended promoting sleep through strategies to optimize the ICU atmosphere (i.e., light and noise level control). Accordingly, end-users perceived these two components of atmosphere as import for a more pleasant environment.[49]

Single-occupancy rooms are standard in new North American ICUs.[29] They have been associated with lower infection transmission rates, more privacy, and improved end-user satisfaction.[47,50,51] The perceptions of participants in this study corroborated these findings. However, nurses identified safety concerns related to increased distance from the patients. Units with lower nurse-to-patient ratios may need to consider this important tradeoff.[50]

The SCCM guidelines suggest considering unit arrangement with rooms clustered into clinical pods when the number of beds exceeds twelve.[4] A recent review of recipients of the SCCM Design Citation ward showed larger units with clinical pods as a rising trend.[26] In our study, there was little support for clustering rooms into separated clinical pods. End-users of FMC-ICU perceived this design feature to be associated with the negative aspects of an overall larger unit including decreased situational awareness and excessive walking. These observations suggest that there may be important tradeoffs between ICU size and organization of space and that opportunities exist to further improve ICU layout and room arrangement

Family areas are designed to satisfy a wide array of visitor needs.[4-6] Flexible room sizes and configurations facilitate accommodation and privacy.[2,4-6,46] Our findings concur with room flexibility as a main attribute enabling private interactions among end-users who wanted to exchange experiences while integrating diverse groups of visitors in the same space. The literature suggests that families rearrange furniture and seating if their needs are not met.[4-6] Social networking may also be impacted by room configuration and location. As patients were discharged to other hospital wards, families seemed to value proximity to the ICU to keep informal relationships and social networks built during the stay.

Another unique contribution of this study is the account of how unit policy and practice guidelines may influence the perceived impact of structural interventions on processes and outcomes of care. This finding highlights a, potentially, overlooked aspect of facility construction that could impede the realization of the full benefits of a new facility.

Methodological Rigor

Numerous authors have proposed frameworks to evaluate the rigor of qualitative research studies.[38,39,52] There is an extensive body of literature on strategies for achieving trustworthiness through enhancing credibility, authenticity, transferability, dependability, and confirmability.[52,53,54,55,56,57] Recent attempts to provide reporting guidelines and a checklist to appraise qualitative research were met with skepticism.[43,56,57] Given the ongoing debate about how to approach rigor in qualitative research, many authors also propose the utilization of equivalent terms to improve understanding about rigor in both quantitative and qualitative

research.[38,52] As such, the qualitative terms credibility and authenticity (findings are authentic portrait of participant's views) are equivalents of internal validation, transferability (how applicable are the findings in other settings) is generalizability, dependability (stable and consistent research processes) is reliability, and confirmability (freedom from researcher bias) is objectivity.[38,52,56,57]

The key aspects of qualitative research rigor applied in this research project were: (1) The research objective is clearly stated and the case study is well described. (2) The case study design is aligned with my philosophical assumptions, interpretative framework and research objectives. (3) Theoretically based purposeful sampling strategy for maximum variation has been applied. (4) Extensive researcher engagement in the field to gain understanding of the context and build rapport with participants. (5) Reflexive considerations of the researcher. (6) Extensive description of the whole research process so readers and other researchers can understand what was done. Other specific strategies to increase credibility (internal validity) that were applied were: ample use of participant's quotes to vividly corroborate a claim or theme, careful consideration of discordant cases, triangulation between different end-user groups using the principles of idea convergence and confirmation, peer examination of the data by healthcare professionals knowledgeable to the context of the FMC-ICU during the initial coding process, and intense exposure of the researcher to the event under study to promote rapport and reduce answers based on social desirability.[53,56,57] To establish dependability (reliability) and confirmability (freedom from researcher bias), I implemented double coding by an experienced qualitative researcher for the first two participants. Coding was followed by a review meeting not seeking agreement or concordance, but rather a discussion session to gather insights from focused discussion and disagreements that would ultimately refine the coding scheme. After the

preliminary analysis of the first six participants, an additional meeting was undertaken to re-discuss the coding scheme and provide further adjustments. Transferability (generalizability) was achieved with thorough step by step description of the research methods to allow readers to make connections between study elements and their own reality.[52]

Key Messages

- End-users find intensive care unit atmosphere important, specifically, natural light and low noise levels.
- Larger spaces require attention to the tradeoffs of size. Larger spaces facilitate family presence and increase the perception of high quality of care. However, safety concerns about increased distance between providers and patients require careful consideration.
- Flexible space configurations, access to hospital amenities (e.g., vending machines, parking), and internet connectivity contribute to visitor satisfaction.
- Design features need to be supported by changes in unit policy, guidelines, and staffing.
- End-user perceptions about the impact of structural interventions on processes of care and outcomes spread across all ICU functional zones and provide informative insights for future ICU design and construction (Table 3):

Limitations

Recall bias is a potential limitation of interviews. I conducted two sets of interviews

following the relocation to attenuate this risk. The format, content, and order of the questions and probing points may have lead participants to comment on or omit specific aspects of their experience. I minimized this by generating an interview guide and probing points with open-ended neutral questions based on a rigorous process to identify design elements that would have the greatest impact participants' experience. Patients were not part of the study population, given the acuity and severity of the diseases commonly admitted to the ICU (i.e., neurologic conditions, delirium, shock) and nature of the care provided (i.e., sedation, mechanical ventilation), I opted to investigate only end-user groups with an ample exposure to the main design features introduced with the new unit.

Selection bias is another risk with small number of participants. Overall, the sample represented the typical diversity of ICU end-users' groups, and frequent visits to the ICU with ample publicity of the interviews ensured inclusion of participants from different shifts and teams. To account for potential researcher bias and ensure that the coding and analysis reflected the voice of end-users, my procedure for review and audit of the coding processes included an experienced qualitative researcher who did not work in the FMC-ICU. Finally, although my study focused on a single newly constructed ICU, I believe that end-user perceptions of evidence-based design features are relevant for other centers.

Chapter VI: Conclusion

This report describes an approach to ICU facility performance evaluation that is complementary to the tools commonly used for this purpose in healthcare. The focus on end-users' perception reveals additional dimensions of the impact of a complex design intervention on everyday clinical and social activities within the unit. Some features such as a pleasant atmosphere with natural light and low noise levels, attention to the tradeoffs of space and size, designing family support areas to encourage family participation in care, and updating patient care policies and staffing to reflect the characteristics of new physical space are particularly important elements to consider when building new ICU. Given the characteristics of the study, the relationships between structure, process, and outcomes are only exploratory, however, they provide preliminary insight on what matters for ICU end-users and can potentially guide new facility construction and additional studies in the field of evidence-based design.

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Tables

Table 1. Patient characteristics

	Early phase	**Late phase**
Age, years, median (IQR)	36 (31-48)	38 (32-49)
Female (%)	54	60
Work experience†, years, median (IQR)	8.5 (3-18)	10 (4-15)
Number of participants	24	15
Nurse	8	5
Respiratory therapist	4	3
Physician	3	3
Other providers	5	0
Support staff	3	1
Family member	1	3

Participant group identified as “Other providers” includes physiotherapists, social workers, and dietitians. “Support Staff” group includes unit clerks and cleaning staff members. †

“Work experience” refers exclusively to healthcare providers.

Table 2. Themes and sub-themes identified from end-user interviews

Themes	**Sub-themes**	**Comments**
Atmosphere		
	Abundant natural light	Bright rooms with ample windows providing natural light and views of nature are calming and boost mood/morale for families and providers (n=105).
	Low noise levels	Quiet environment improves concentration, task completion, and teamwork (n=40). Sign of respect for patients.

Themes	Subthemes	Comments
Physical spaces		
	Single-occupancy rooms	Positive aspects (n=69, e.g., privacy, family presence at bedside). Negative aspects (n=30, e.g., safety concerns given increased distance between patients and providers).
	Rooms clustered into clinical pods	Positive aspects (n=4, e.g., ICU seems less busy). Negative aspects (n=75, e.g., less situational awareness).

Themes	Subthemes	Comments
	Medication rooms	Positive aspects: Large room for multiple users at peak time (n=9). Quieter with less distraction during preparation (n=2) Negative aspects: nurses can't hear bedside alarms (n=4). Need for extra staff coverage (n=2).
	Tradeoffs of larger spaces	Positive aspects (n=56) of larger spaces such as facilitated teamwork activities (e.g., rounds without interruption) are worth the negative aspects including patient safety concerns. Additional measures are necessary to mitigate some negative aspects (n=8).

Themes	**Subthemes**	**Comments**
Family participation in care		
	Family support areas	More space in family areas is functional (n=17), with location (n=19) and flexibility (n=2) important.
	Social networks	Location and configuration impact informal networks with other families (n=2). Connectivity for family members (n=2).
Equipment		
	Usability	Positive: Innovative equipment (n=9). Negative: Challenges using new equipment in early phase (n=8).

Themes	Subthemes	Comments
	Storage	Positive: Same storage configuration in all clinical pods (n=8). Supplies in the room (n=2).
	Provider connectivity	Positive: More computers to access and document clinical information (n=19)

Numbers in parentheses represent the total number of comments about a sub-theme.

Table 3. Potential relationship between Design Features, Processes and Outcomes of care.

Design Features (Structure)	**Processes**	**Outcomes**
Patient Care Zone		
1. Ample windows	Abundant natural light Access to views of nature	Increased end-user satisfaction Potential for less patient anxiety and stress*
2. Adjustable light level	Improved day/night cycles	Increased end-user satisfaction
3. Noise control measures	Lower noise levels, improved teamwork, calmer visitors, improved visitor-provider interactions Fewer interruptions, improved provider concentration	Increased end-user satisfaction Potential for improved task completion*

Design Features (Structure)	**Processes**	**Outcomes**
4. Single-occupancy rooms	Increased visitor presence at bedside, improved visitor-provider interactions Difficult to hear bedside alarms	Improved end-user satisfaction, potential for improved confidentiality/privacy* Potential for more adverse events*
5. Large patient care area	Increased number of providers at bedside, improved teamwork, improved provider-provider interaction More walking, isolated providers, decreased provider-provider interaction	Increased end-user satisfaction Decreased end-user satisfaction

Design Features (Structure)	Processes	Outcomes
6. Rooms clustered into clinical pods	Decreased provider situational awareness, fewer provider social interactions, more walking, increased number of providers required for coverage, decreased teamwork	Decreased end-user satisfaction, potential for more adverse events*
	Easier identification of caring team, reduced exposure to activities not related to patient care	Improved end-user satisfaction
7. Storage of supplies in the room	Increased access and utilization of supplies	Improved end-user satisfaction
8. More computers	Improved medical documentation	Improved end-user satisfaction

9. New equipment training	Improved early usability	Improved end-user satisfaction, potential for fewer adverse events*
10. Decentralized nursing stations	Higher noise levels	Decreased end-user satisfaction

Design Features (Structure)	Processes	Outcomes
Clinical Support Zone		
1. Restricted access to medication room	Fewer interruptions during medication preparation Difficult to hear bedside alarms	Potential for fewer adverse events Potential for more adverse events*
2. Large medication room	Improved utilization by multiple providers at peak hours	Potential for fewer adverse events*, improved end-user satisfaction
Unit Support Zone		
1. Provider areas close to the ICU	Increased utilization by providers	Improved end-user satisfaction
2. Large provider support areas	Increased utilization by providers	Improved end-user satisfaction

3. Administrative offices close to the ICU	Increased provider-decision-maker interactions	Improved end-user satisfaction
4. Same storage configuration in all clinical pods	Improved access to and utilization of supplies	Improved end-user satisfaction
Family Support Zone		
1. Family area location close to areas of interest to visitors	Increased visitor presence, improved visitor-visitor interaction, easier wayfinding	Improved end-user satisfaction
2. Flexible family area configuration	Easier to accommodate diverse needs	Improved end-user satisfaction
3. Access to free internet and telephone	Improved communication, increased visitor presence	Improved end-user satisfaction

Framework developed merging the Donabedian conceptual model and the 2012 Society of Critical Care Medicine Guidelines for Intensive Care Unit Design (support zones). Design Features (STRUCTURE) are design elements perceived as important by study participants. PROCESSES of care are end-user activities while giving or receiving healthcare-related actions. OUTCOMES of care are the effects perceived by end-users. End-users may include healthcare providers, support staff, and family members. * Outcomes marked as potential given the exploratory nature of the relationships based on end-user perceptions.

Appendix A: Contributions of authors to the manuscript

Mauricio Beller Ferri conceived the research question, proposed the study design, interviewed study participants, transcribed the audiotapes, performed the qualitative data analysis, drafted the first version of the submitted manuscript, and wrote all thesis chapters. David A Zygun, as a member of the supervisory committee, approved the study design, contributed to interpretation of the qualitative data analysis, and provided important revisions to the resulting manuscript. Alexandra Harrison, as a member of the supervisory committee and expert in qualitative research, approved the study design, contributed to the qualitative data analysis, and provided important revisions to the resulting manuscript. Henry Thomas Stelfox, as the thesis supervisor, contributed to the conception of the research question, approved the study design, assisted with qualitative data analysis, and provided important revisions to the resulting manuscript. All authors read and approved the final version of the manuscript that was submitted for peer-review and published on BMC Anesthesiology on April 2015. The manuscript-based thesis submitted to the Faculty of Graduate Studies is a presentation of this work.

Appendix B: Information to participants

The text below was printed and handed out to the Foothills Medical Centre Intensive Care Unit end-users or sent electronically via email upon request.

Information Sheet

Project title: "Performance Evaluation of the Foothills Medical Centre-McCaig Centre new Intensive Care Unit. A Quality Improvement Approach."

Investigators: Dr H Tom Stelfox, Intensivist – Foothills Hospital.

Dr Mauricio Ferri, Clinical Fellow – ICU.

To all potential study participants,

Thank you for taking the time to read this information sheet. The interview is part of an approved research project at the Department of Community Health Sciences at the University of Calgary. Our aim is to study the impact of moving to a brand new ICU facility on the way we provide care for our patients and also the impact on their outcomes. This should hopefully help improve our unit in the future, as well as the way we plan and build new ICU's.

The interview will be audio taped and is expected to take approximately 20 minutes. I will ask about your opinion on the new ICU facility on many different aspects. It is completely voluntary and confidential. Your participation will not affect the care provided to you or

your family member. I will not collect any information that could identify you. At any time, you can stop the interview if you wish to do so.

I will be doing interviews today from _____ to_____ in room number _____ at the ICU pod____. Feel free to just walk in, no appointment is necessary. If you prefer, we can book a future time for your convenience. Please contact me (Mauricio Ferri), at 403 2107370 or mbellerferri@gmail.com if you have any questions regarding this study.

If you have any questions concerning your rights as a possible participant in this research, please contact The Chair of the Conjoint Health Research Ethics Board at the Office of Medical Bioethics, 403-220-7990, email: omb@ucalgary.ca, or the Ethics Resource Officer, Internal Awards, Research Services, University of Calgary, at 403-220-3782.

H Tom Stelfox

Mauricio Ferri

Appendix C: Interview Guide

Questions	Probing points
1. Positive and negative aspects of the new ICU design?	Atmosphere Single rooms Geographic location
2. Is your job easier or more difficult because of the facility design?	Bedside technology Access to supplies Medication room/errors
3. Could you describe a specific event when there was an emergency situation and the space facilitated/hindered your delivery of patient care?	Intra-unit code activation system Cardiac arrest team/ Medical emergency team response time.
4. In terms of workflow how would you describe the new FMC-ICU facility?	
5. In terms of communication how does the FMC-ICU fare?	

Questions	Probing points
6. Besides your job, how does the facility affect your work team, interaction with other care providers, patients and family? † How does the facility affect your interaction with care providers, your loved-one, and other families?	Social networks. Providers support areas. Family support areas.
7. If you could fix one thing about the new ICU what would that be?	
8. Which aspects of the new ICU do you like the most?	Layout, single rooms, atmosphere, family areas, or any other aspect mentioned by the respondent.
9. Is there anything else you would like to tell us about the new ICU building?	

Appendix D: Manuscript published on BMC Anesthesiology in April 2015

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Evidence-based design in an intensive care unit: End-user perceptions.

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Abstract

Background

The objective of this study was to describe end-user impressions and experiences in a new intensive care unit built using evidence-based design.

Methods

This qualitative study was comprised of early (2-3 months after opening) and late (12-15 months after opening) phase individual interviews with end-users (healthcare providers, support staff, and patient family members) of the newly constructed Foothills Medical Centre intensive care unit in Calgary, Canada. The study unit was the recipient of the Society of Critical Care Medicine Design Citation award in 2012.

Results

We conducted interviews with thirty-nine ICU end-users, twenty-four in the early phase and fifteen in the late phase. We identified four themes (eleven sub-themes): atmosphere (abundant natural light and low noise levels), physical spaces (single occupancy rooms, rooms clustered into clinical pods, medication rooms, and tradeoffs of larger spaces), family participation in care (family support areas and social networks), and equipment (usability, storage, and providers connectivity). Abundant natural light was the design feature most frequently associated with a pleasant atmosphere. Participants emphasized the tradeoffs of size and space, and reported that the benefits of additional space (e.g., fewer interruptions due to less noise) out-weighed the disadvantages (e.g., greater distances between patients, families and providers). End-users advised that local patient care policies (e.g., number of visitors allowed at a time) and staffing needed to be updated to reflect the characteristics of the new facility design.

Conclusions

End-users identified design elements for creating a pleasant atmosphere, attention to the tradeoffs of space and size, designing family support areas to encourage family participation in care, and updating patient care policies and staffing to reflect the new physical space as important aspects to consider when building intensive care units. Evidence-based design may optimize ICU structure for patients, patient families and providers.

Keywords

Critical care, facility design and construction, health care evaluation mechanisms, qualitative research, post-occupancy evaluation

Background

Expanding health services and design-focused research in conjunction with a growing emphasis on quality improvement in healthcare systems has contributed to the emergence of evidence-based design [1–3]. Evidence–based design is defined as the application of the best available knowledge from research and practice to take design decisions (i.e., healthcare physical environment) [3]. This novel approach extends beyond minimum construction standards and aims to recommend healthcare facility design features that improve clinical performance and create “healing environments” [1, 3, 4].

Evidence-based design may be particularly relevant for intensive care units (ICU) in which patients have life-threatening conditions and the model of care is based on multidisciplinary teamwork. Intensive care units leaders have been challenged to increase quality, reliability, and safety of service delivery in recent years [5–7]. Facility design affects the

social behavior of end-users. It potentially shapes the way patients, families, and providers interact and impacts processes of care and patient outcomes [1, 6, 8, 9].

The objective of this study was to describe end-user impressions and experiences in a new ICU constructed using evidence-based design [10]. The setting for our study was the new Foothills Medical Centre intensive care unit (FMC-ICU) in Calgary, Canada, recipient of the Society of Critical Care Medicine (SCCM) ICU Design Citation award in 2012 [11]. Clinicians and design experts collaborated in the planning process that started with defining their vision of the ideal facility and developing guidelines which incorporated state-of-the-art technology and functionality in a pleasant environment for end-users. Subsequently, the planning team used life-size simulation to determine room configuration and equipment disposition [12]. The new FMC-ICU incorporated design features such as single-occupancy rooms, patient care rooms clustered into clinical pods, and dedicated family support areas [1, 3]. We took advantage of the opening of the FMC-ICU to determine end-user impressions and experiences with these evidence-based design features.

Methods

Approach

This was a qualitative study comprised of interviews with the end-users of the FMC-ICU. We conducted two phases of data collection to account for both the "settling–in" period, when problems are most frequent, and the "halo effect", associated with moving to a new facility [4]. Early phase interviews were conducted two to three months after the facility opened and late phase interviews were conducted twelve to fifteen months after it opened. We obtained verbal informed consent from all study participants. The Conjoint Health Research Ethics Board at the

University of Calgary approved the study protocol (E-24609).

We generated an interview guide using a focused literature review, examination of local guidelines for ICU design, and interviews with four key informants who served on the local design committee. The interview guide (see additional file 1) consisted of open-ended questions to encourage participants to freely reflect on their impressions and experiences with the new FMC-ICU as well as probing questions regarding specific evidence-based design features.

We utilized a non-probability sampling strategy (maximum variation purpose sampling) to obtain a wide range of perspectives representing the typical diversity of end-users' groups experiencing the new ICU facility. We included healthcare providers, support staff and patient family members. The study was locally publicized with electronic messages to inform providers of the purpose, time, and location of the interviews. End-users were recruited during typical working shifts to facilitate participation.

Analysis

We analyzed verbatim transcripts of individual, semi-structured, in-depth audiotaped interviews. We used traditional qualitative analysis with an iterative and reflexive process [13, 14]. This involved multiple reviews of the transcripts, identifying key concepts as codes, using constant comparison to refine and modify the codes, grouping broad topics into themes through careful reading and re-reading of the data. One author (MF) coded and analyzed six transcripts and concomitantly developed a qualitative codebook to define, code, and synthetize the core ideas expressed by the participants. Subsequently, we divided themes into sub-themes that described the findings in more detail. All authors reviewed and revised the coding scheme which one author (MF) subsequently applied to all transcripts with minor adjustments in the following

iterations.

As a final step in the data analysis, we developed a theoretical framework to classify and visualize end-user perceptions of structure, process, and outcomes across the ICU functional zones (i.e., physical areas housing a set of interrelated functions) [1]. We merged the Donabedian conceptual model for quality of healthcare delivery and the 2012 SCCM Guidelines for Intensive Care Unit Design to inform our approach [1, 15, 16].

Results

We interviewed thirty-nine end-users of the FMC-ICU, twenty-four in the early phase and fifteen in the late phase. Table 1 describes participants' characteristics grouped by study phase. Our analysis produced four themes (atmosphere, physical spaces, family participation in care, and equipment) and eleven sub-themes (Table 2).

Atmosphere

All participants mentioned a brand new ICU with a pleasant atmosphere as a major positive impact in both phases. The effects of a pleasant atmosphere were apparent for patient families and providers, who both reported that they resulted in calmer families more willing to interact with the provider team. The most impactful elements of atmosphere were natural light and lower noise levels.

"Well, number one, it's brand new (…) So that's very impressive. The room that my

husband is in is wonderful (…) size-wise, beautiful view."

Abundant natural light. It was the most frequent component of a pleasant atmosphere described. The majority of participants highlighted the perceived benefits of a brighter facility with more windows. Three noted that the ICU was bright during the day and adequately dark during the night, creating conditions for day/night cycle. The related construct "views of nature" was identified as having a positive impact on the mood and morale of end-users.

"It's bright, because so much of our work is dark. You know, it's heavy, it's emotion-laden, it's fearful, it's stressful, there's a lot of death, there's loss. You know, it's depressing. So it is really important to have a bright, colourful environment"

"At night it's darker I think, whereas before we had [artificial] skylights and … it wasn't always as dark."

Lower noise levels. Participants associated lower noise levels with better concentration and ability to complete clinical tasks, such as rounding, with fewer interruptions (n=20). They perceived lower noise levels were a sign of respect to patients and family members. As a negative point, the unit was perceived as noisy during handover between work shifts. Providers suggested the cause was the bedside design with decentralized nursing stations and two teams of nurses sharing the same workspace.

"The most significant change that I have seen is the fact that the unit is very quiet. You can round in an ambiance that allows you to concentrate on -- on your work. You no longer have the multiple distractions that we used to have in the -- in the previous unit (...) It was so noisy and so very many interruptions that oftentimes I was concerned with my ability to -- to maintain my -- my concentration"

Physical spaces

End-users identified three physical spaces as important: single-occupancy rooms, rooms clustered into clinical pods, and medication rooms. Many end-users made both positive and negative comments about overall unit size and space. Some identified tradeoffs of size and space, including the challenge of larger physical spaces resulting in greater distances between patients, patient families and providers.

Single-occupancy rooms. Sixty-nine comments described positive aspects of single-occupancy rooms: privacy for patients and families (n=20), confidentiality during clinical encounters (n=25), room to accommodate providers during routine and emergency care, and presence of family members at the bedside (n=18). Six participants indicated that single-occupancy rooms allowed for better infection prevention and control practices. Three family members commented that the care provided in single-occupancy rooms was perceived as more individualized.

" There's just the space to move, there's space to get equipment in and out, there's space to get people in and out. It just makes it easier to actually do your job 'cause there's physically

the space to do it"

In the early phase, participants mentioned safety concerns, including increased distance from patients, lack of visual contact, and perceived difficulty hearing alarms (n=12), feeling isolated from other providers (n=8), and concerns about calling for help from inside the room (n=5). In the late phase, nurses did not mention isolation but still commented on concerns about calling for help from inside the room (n=3) and the distance from the patients (n=2).

" I would say the four walls around us kind of hinders maybe sometimes getting help. Like there used to be curtains between us, and you could see the feet shuffling underneath and you'd say hey you, you know, I need help. Now it's not quite as easy to just call out for help"

"... before you could just open the curtains, you could see six patients, so you could help whoever was crashing, here you can't because you just can't see more than two patients at a time."

Rooms clustered into clinical pods. There were seventy-five comments on negative aspects of patient rooms clustered into clinical pods. The comments suggested that the clinical pods were excessively spread-out, which hindered social interaction and camaraderie among providers (n=11) and reduced visual contact between providers, "hampering" situational

awareness (n=20). Although participants thought it was more difficult to find people within the unit, this was not perceived to impact informal professional support networks (e.g., asking someone else for clinical advice) (n=9). Nine participants indicated the layout was a barrier to diverting providers to busier areas within the ICU when help was needed. Physicians noted increased walking distances made it more physically demanding to look after patients in different pods. Nurses commented that cross coverage of patients was more difficult with larger physical spaces, and that this challenge had not been anticipated prior to opening the new ICU (n=6).

"*Again, the physical plant is so spread out; when we have to cover you don't know what's going on in the units (clinical pods). And for us, that's tough when you're on call, right? Like if somebody's really sick, they have to be able to get a hold of you, you have to get there. So that's one thing."*

" *We used to always be so close together that we were all tight in the same place, which led to a more social atmosphere, I found. Sometimes you feel—I don't want to say isolated, but sometimes you feel like everyone's very far away and there's not that camaraderie and immediately social aspect."*

There was no mention of any positive aspects of rooms clustered into clinical pods in the early phase. In the late phase, four participants mentioned that this arrangement facilitated identification of the ICU team by family members and consultants. They also commented that

separate clinical pods allowed end-users to avoid exposure to events occurring in other areas of the ICU (e.g., noise and activity associated with movement of patients in and out of the ICU or stress of patient resuscitation).

"...I like the separate pod idea. Because if you were in the open unit, when it was busy in one side, it felt like the whole unit was busy, right? And it would be just wearing on you."

Medication rooms. Nurses mentioned the impact of a dedicated and distinct medication room twenty times. The size allowed multiple providers to use it simultaneously at peak medication hours (n=9). Lower noise levels were reported to lead to perceptions of less distraction during medication preparation, fewer errors and increased safety (n=2). The main negative point was the need for nurses to have their patients monitored by a colleague while using the medication room because they could not hear alarms from the room (n=4).

" I guess it's nice that it's divided up—three, one in each pod. It's not a mad rush and first thing in the morning, you're not fighting. So I guess that's something."

"If I have to go and get a medication, it's hard to hear your patient, right? If there's an alarm or something, … and sometimes if you have a really sick patient, it's a little bit sketchy running to get a med."

Tradeoffs of larger spaces. All participants indicated that the positive aspects of more space outweighed the negative. End-users suggested that more space facilitated the presence of family members at the bedside. They also felt that more contact with the provider team reassured families about the quality of care provided and improved the perception of coordinated teamwork. Providers commented that larger hallways and more space at the bedside facilitated seamless teamwork activities including fewer interruptions during multidisciplinary clinical

rounds. Nurses mentioned that the implementation of a wireless provider-to-provider communication system (n=5) was perceived as good solution for difficulties created by a larger unit. Providers felt subsequent improvements in the emergency response system within the ICU (i.e., providers could trigger a local code call from inside the room with the touch of one button) increased safety in a larger space (n=3). In addition, end-users commented that local policy and guidelines were outdated and limited the perception of improvement brought by larger spaces (e.g., policies restricting the number of visitors at the bedside to two).

Family participation in care

Family support areas. End-users identified the location of family areas and other hospital amenities (n=19). Close but physically separated from the patient care area were identified as being important to end-users. Participants highlighted positive (n=6) and negative (n=3) aspects of family support areas size. They suggested larger areas were important to accommodate larger groups of visitors in a comfortable way. They indicated they helped a diverse group of visitors to simultaneously use the space. In contrast, one provider mentioned that large areas felt cold and impersonal. Conversely, smaller rooms were more intimate, but visitors "camped" in them, limiting access for others.

"So it would be nice if we had, you know, a big room, a big waiting room with some small rooms that could be used for privacy for some people, right, within that big unit, that big… big waiting room. So it seems a bit cold in there. "

" But I actually think that they are very much appreciated by families and you're making a statement, which is (...) you are thinking about not just the patients, not just the staff, but the families that often have a 24-hour presence as long as people are in the ICU"

Social networks. End-users suggested that the family support area location was crucial to developing informal social networks among visitors facilitating way-finding and transitions of care out of the ICU. A healthcare provider questioned if more flexible rooms, with smaller and more private areas, could enhance interactions between families of different patients, facilitate sharing of experiences, and help create family networks. Two family members appreciated the availability of computers with internet access and free public telephones, which enabled communication with relatives and friends.

"And it helps to talk to people, I think (...) Most people want to talk about their situation, right?"

Equipment

Usability. Participants commented on equipment usability seventeen times. In the early phase, providers identified negative aspects of new equipment usability such as problems getting used to the dual pendant-mounted system, with medical gases and power outlets suspended from

the ceiling (n=4), and malfunctioning automatic doors, impeding rapid access between units (n=4). However, in the late phase, they indicated that having innovative equipment (e.g., ability to display patient monitor information on the room television screen) was perceived as positive and helpful to patient care (n= 9).

"The arms are very frustrating because before you could decide where your ventilator was, where your IV pumps and if you did a bronch, I would pull my IV pumps to the foot of the bed so it would be out of everyone's way."

Storage. Participants indicated that the storage of supplies and equipment needed to be identical in each clinical pod so that providers knew where to find them (n=5). Two nurses indicated that the presence of supplies within patient rooms facilitated workflow.

Provider connectivity. Providers perceived increased computer availability as a positive feature to access information and document clinical care (n=19). In contrast, two physicians suggested it could be distracting from clinical tasks.

"Also the increased availability of lots of computers. So you're not fighting for space or a computer to do recording."

Discussion

Our analysis provides an opportunity to understand how evidence-based design impacts

the impressions and experiences of ICU end-users. Abundant natural light and low noise levels improved the perception of a pleasant atmosphere. Participants emphasized tradeoffs of size and space, identifying safety concerns of increased distance between end-users. Physical and functional characteristics of family support areas influenced the reported integration of family members in patient care. Unit polices needed adjustment to reflect the new facility design.

Despite a growing body of evidence, conflicting study results have not allowed conclusive identification of essential design features to transform ICUs into "healing environments" [8, 17, 18]. However, the SCCM ICU design guidelines recommended features that were identified as important in our study included natural light, low noise levels, single occupancy-rooms, unit arrangement with rooms clustered into clinical pods, and family support areas [1].

The guidelines suggested natural light is essential and recommended at least one window per patient bed area [1]. This is supported by the findings in this study since abundant natural light was the most frequently identified feature for a pleasant atmosphere. However, a recent secondary analysis of a large cohort study in patients with brain injury did not show improvement in patient outcomes with the presence of windows in ICU rooms [17].

End-users in this study described benefits of lower noise levels. In addition to facilitating patient sleep, which has been described elsewhere [19-22], they suggested it improved concentration and task completion (e.g., clinical rounds) and thought quietness was a sign of respect for the families. In agreement with previous studies, one provider commented that family members appeared calmer and more willing to engage with the team as a result of a quieter atmosphere [8, 18].

The latest SCCM guidelines for the management of pain, agitation, and delirium in adult patients recommended promoting sleep through strategies to optimize the ICU atmosphere (i.e., light and noise level control). Accordingly, end-users perceived these two components of atmosphere as import for a more pleasant environment [23].

Single-occupancy rooms are standard in new North American ICUs [19]. They have been associated with lower infection transmission rates, more privacy, and improved satisfaction [20,24–26]. The perceptions of end-users in this study corroborated these findings. However, nurses identified safety concerns related to increased distance from the patients. Units with lower nurse-to-patient ratios may need to consider this important tradeoff [27].

The SCCM guidelines suggest considering unit arrangement with rooms clustered into clinical pods when the number of beds exceeds twelve [1]. A recent review of recipients of the SCCM Design Citation ward showed larger units with clinical pods as a rising trend [27]. In our study, there was little support for clustering rooms into separated clinical pods. End-users of FMC-ICU perceived this design feature to be associated with the negative aspects of an overall larger unit including decreased situational awareness and excessive walking. These observations suggest that there may be important tradeoffs between ICU size and organization of space and that opportunities exist to further improve ICU layout and room arrangement

Family areas are designed to satisfy a wide array of visitor needs [1–3]. Flexible room sizes and configurations facilitate accommodation and privacy [1–3, 8, 18]. Our findings concur with room flexibility as a main attribute enabling private interactions among end-users who wanted to exchange experiences while integrating diverse groups of visitors in the same space. The literature suggests that families rearrange furniture and seating if their needs are not met [1–

3]. Social networking may also be impacted by room configuration and location. As patients were discharged to other hospital wards, families seemed to value proximity to the ICU to keep informal relationships and social networks built during the stay.

Another unique contribution of this study is the account of how unit policy and practice guidelines may influence the perceived impact of structural interventions on processes and outcomes of care. This finding highlights a, potentially, overlooked aspect of facility construction that could impede the realization of the full benefits of a new facility.

Key Messages

Our interpretation of end-user perceptions of the impact of structural changes on experiences provides important insights that can inform the design of future ICUs (Table 3):

- End-users find intensive care unit atmosphere important, specifically, natural light and low noise levels.
- Larger spaces require attention to the tradeoffs of size. Larger spaces facilitate family presence and increase the perception of high quality of care. However, safety concerns about increased distance between providers and patients require careful consideration.
- Flexible space configurations, access to hospital amenities (e.g., vending machines, parking), and internet connectivity contribute to visitor satisfaction.
- Design features need to be supported by changes in unit policy, guidelines, and staffing.

Limitations

Recall bias is a potential limitation of interviews. We conducted two sets of interviews

following the relocation to attenuate this risk. The format, content, and order of the questions and probing points may have lead participants to comment on or omit specific aspects of their experience. We minimized this by generating an interview guide and probing points with open-ended neutral questions based on a rigorous process to identify design elements that would have the greatest impact participants' experience. Selection bias is another risk with small number of participants. Overall, the sample represented the typical diversity of ICU end-users' groups, and frequent visits to the ICU with ample publicity of the interviews ensured inclusion of participants from different shifts and teams. To mitigate potential personal biases and ensure that the coding and analysis reflected the voice of end-users, our review and audit of the coding process included an experienced qualitative researcher who did not work in the FMC-ICU. Finally, although our study focused on a single newly constructed ICU, we believe that end-user perceptions of evidence-based design features are relevant for other centers.

Conclusion

End-users identified a pleasant atmosphere (natural light and low noise levels), attention to the tradeoffs of space and size, designing family support areas to encourage family participation in care, and updating patient care policies and staffing to reflect the characteristics of new physical space as important elements to consider when building intensive care units. Evidence-based design may be used to optimize ICU structure for patients, patient families, and providers.

Abbreviations

ICU: Intensive Care Unit

FMC-ICU: Foothills Medical Centre Intensive Care Unit

SCCM: Society of Critical Care Medicine

IQR: Inter quartile ranges

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MF conceived the research question, contributed to study design, performed the interviews, contributed to the qualitative data analysis, and drafted the first version of the manuscript. DAZ contributed to study design, qualitative data analysis, and provided important input for drafting the manuscript. AZ contributed to study design, qualitative data analysis, and provided important input for drafting the manuscript. HTS conceived the research question, contributed to study design and qualitative data analysis, and provided important input in the successive revisions of the manuscript. All authors read and approved the final version of the manuscript.

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Table 1. Participant characteristics

	Early phase	Late phase
Age, years, median (IQR)	36 (31-48)	38 (32-49)
Female (%)	54	60
Work experience†, years, median (IQR)	8.5 (3-18)	10 (4-15)
Number of participants	24	15
Nurse	8	5
Respiratory therapist	4	3
Physician	3	3
Other providers	5	0
Support staff	3	1
Family member	1	3

Participant group identified as "Other providers" includes physiotherapists, social workers, and dietitians. "Support Staff" group includes unit clerks and cleaning staff members. † "Work experience" refers exclusively to healthcare providers.

Table 2. Themes and sub-themes identified from end-user interviews

Themes	Sub-themes	Comments
Atmosphere		
	Abundant natural light	Bright rooms with ample windows providing natural light and views of nature are calming and boost mood/morale for families and providers (n=105).
	Low noise levels	Quiet environment improves concentration, task completion, and teamwork (n=40). Sign of respect for patients.
Physical spaces		
	Single-occupancy rooms	Positive aspects (n=69, e.g., privacy, family presence at bedside). Negative aspects (n=30, e.g., safety concerns given increased distance between patients and providers).
	Rooms clustered into clinical pods	Positive aspects (n=4, e.g., ICU seems less busy). Negative aspects (n=75, e.g., less situational awareness).

Themes	Sub-themes	Comments
	Medication rooms	Positive aspects: Large room for multiple users at peak time (n=9). Quieter with less distraction during preparation (n=2) Negative aspects: nurses can't hear bedside alarms (n=4). Need for extra staff coverage (n=2).
	Tradeoffs of larger spaces	Positive aspects (n=56) of larger spaces such as facilitated teamwork activities (e.g., rounds without interruption) are worth the negative aspects including patient safety concerns. Additional measures are necessary to mitigate some negative aspects (n=8).
Family participation in care		
	Family support areas	More space in family areas is functional (n=17), with location (n=19) and flexibility (n=2) important.
	Social networks	Location and configuration impact informal networks with other families (n=2). Connectivity for family members (n=2).
Equipment		

Themes	Sub-themes	Comments
	Usability	Positive: Innovative equipment (n=9). Negative: Challenges using new equipment in early phase (n=8).
	Storage	Positive: Same storage configuration in all clinical pods (n=8). Supplies in the room (n=2).
	Provider connectivity	Positive: More computers to access and document clinical information (n=19)

Numbers in parentheses represent the total number of comments about a sub-theme.

Table 3. Potential relationship between Design Features, Processes and Outcomes of care.

Design Features (Structure)	**Processes**	**Outcomes**
Patient Care Zone		
1. Ample windows	Abundant natural light Access to views of nature	Increased end-user satisfaction Potential for less patient anxiety and stress*
2. Adjustable light level	Improved day/night cycles	Increased end-user satisfaction

3. Noise control measures	Lower noise levels, improved teamwork, calmer visitors, improved visitor-provider interactions	Increased end-user satisfaction
	Fewer interruptions, improved provider concentration	Potential for improved task completion*
4. Single-occupancy rooms	Increased visitor presence at bedside, improved visitor-provider interactions	Improved end-user satisfaction, potential for improved confidentiality/privacy*
	Difficult to hear bedside alarms	Potential for more adverse events*

5. Large patient care area	Increased number of providers at bedside, improved teamwork, improved provider-provider interaction	Increased end-user satisfaction
	More walking, isolated providers, decreased provider-provider interaction	Decreased end-user satisfaction

6. Rooms clustered into clinical pods	Decreased provider situational awareness, fewer provider social interactions, more walking, increased number of providers required for coverage, decreased teamwork Easier identification of caring team, reduced exposure to activities not related to patient care	Decreased end-user satisfaction, potential for more adverse events* Improved end-user satisfaction
7. Storage of supplies in the room	Increased access and utilization of supplies	Improved end-user satisfaction
8. More computers	Improved medical documentation	Improved end-user satisfaction

9. New equipment training	Improved early usability	Improved end-user satisfaction, potential for fewer adverse events*
10. Decentralized nursing stations	Higher noise levels	Decreased end-user satisfaction
Clinical Support Zone		
1. Restricted access to medication room	Fewer interruptions during medication preparation Difficult to hear bedside alarms	Potential for fewer adverse events Potential for more adverse events*
2. Large medication room	Improved utilization by multiple providers at peak hours	Potential for fewer adverse events*, improved end-user satisfaction
Unit Support Zone		

1. Provider areas close to the ICU	Increased utilization by providers	Improved end-user satisfaction
2. Large provider support areas	Increased utilization by providers	Improved end-user satisfaction
3. Administrative offices close to the ICU	Increased provider-decision-maker interactions	Improved end-user satisfaction
4. Same storage configuration in all clinical pods	Improved access to and utilization of supplies	Improved end-user satisfaction
Family Support Zone		
1. Family area location close to areas of interest to visitors	Increased visitor presence, improved visitor-visitor interaction, easier wayfinding	Improved end-user satisfaction
2. Flexible family area configuration	Easier to accommodate diverse needs	Improved end-user satisfaction

3. Access to free internet and telephone	Improved communication, increased visitor presence	Improved end-user satisfaction

Framework developed merging the Donabedian conceptual model and the 2012 Society of Critical Care Medicine Guidelines for Intensive Care Unit Design (support zones). Design Features (STRUCTURE) are design elements perceived as important by study participants. PROCESSES of care are end-user activities while giving or receiving healthcare-related actions. OUTCOMES of care are the effects perceived by end-users. End-users may include healthcare providers, support staff, and family members. * Outcomes marked as potential given the exploratory nature of the relationships based on end-user perception.