© The Author(s), 2025

Computer Supported Cooperative Work (CSCW) (2025) 34:949–977
https://doi.org/10.1007/s10606-025-09526-0

RESEARCH

Repair Work in Electronic Medication Management

Morten Hertzum*[1], Gunnar Ellingsen[2] & Camilla Bjørnstad[3]
*[1]*Roskilde University, Roskilde, Denmark (E-mail: mhz@ruc.dk);* [2]*UiT – The Arctic University of Norway, Tromsø, Norway (E-mail: gunnar.ellingsen@uit.no);* [3]*University Hospital of North Norway, Tromsø, Norway (E-mail: Camilla.Hilda.Bjornstad@sykehusapotek-nord.no)*

Accepted: 25 July 2025

Abstract. High-quality hospital care requires careful medication management. The infrastructure in place to avert errors in medication management involves formal work procedures, elaborate electronic systems, and, we argue, continual repair work. Repair is the work required to restore things to working order after a breakdown. In this study, we analyze the repair work performed by the healthcare professionals tasked with two electronically supported medication-management processes at hospitals in Norway: medication reconciliation and closed-loop medication management. On the basis of interviews and supplementary material, we find that the repair work involved in these two activities is collaborative, continuous, and critical. It is collaborative in that it is performed by physicians, pharmacists, and nurses and, thereby, neither assigned to a single person nor to a group of designated repairers. It is continuous because the repairs do not fix the causes of the breakdowns but merely restore the individual instance of medication management to working order. It is critical in the double sense that repair work is a requirement for quality medication management and that quality repair work is also a requirement. We discuss the implications of the repair work, including the consequences of variation in the achieved level of repairedness.

Keywords: Healthcare, Improvisation, Infrastructuring, Medication management, Repair work

1 Introduction

Medication is key to the effective treatment of diseases but, at the same time, poses risks to patients. Central to these risks are medical errors, which continue to be among the leading causes of mortality and morbidity in developed countries (Makary and Daniel 2016; Phillips and Bredder 2002). To avoid such errors, hospitals devote considerable resources to medication management, that is, to ensuring that the right patient gets the right medication in the right dose, through the right route, and at the right time (Choo et al. 2010). Medication management amounts to a sizable infrastructure that involves a range of work practices, an arrangement of electronic systems, and, we argue, a continual need for repair. In this study, we analyze the repair work involved in two electronically supported

medication-management activities: medication reconciliation and closed-loop medication management.

Repair work (Jackson 2014; Strebel et al. 2019) is the everyday response to cracks and disruptions in the order of things. These cracks and disruptions happen because the infrastructures that undergird normal work practices wear down, get out of step, presume rigid workflows, encounter unanticipated cases, employ conflicting standards, disregard situational features, suffer resource scarcity, manipulate complex data, hinge on uncertain judgments, face exacting deadlines, and are otherwise used in ways that cause breakdowns. While research on infrastructures tend to emphasize how they are sunk into the background and become visible only on breakdown, research on repair shifts attention to the work that goes into upholding normal work practices in the face of continual breakdowns (e.g., Graham and Thrift 2007; Henke 2019). Because breakdowns in medication management may have fatal consequences for patients, it is crucial to uphold high quality standards. Formal work procedures and elaborate electronic systems serve this purpose but they also increase the complexity of the aggregate infrastructure for medication management. When infrastructural complexity increases, the occasions for breakdown and, hence, the need for repair also increase (Graham and Thrift 2007). Thereby, it becomes safety critical that medication management is consistently and dependably repaired.

On this basis, we ask the research question: *How is medication management at hospitals repaired by those performing it and what are the implications for hospital infrastructures?* To answer this question, we analyze a case about medication reconciliation and another about closed-loop medication management, both from hospitals in Norway. The cases represent two complementary means of ensuring the quality of medication management – the former concerns the early stage of medication management, the latter its later stages. Our analysis shows how both are kept in working order. That is, the overall contribution of bringing out the repair work involved in medication management is to subject to analysis the constant work involved in maintaining this order. Conceptually, we discuss how repair differs from articulation work, emphasizing that articulation is a common mode of repair but only in the situations where the repair is accomplished by allocation, coordination, and scheduling among the involved actors. Thereby, repair and articulation work are overlapping, but different, concepts. Despite formal procedures and electronic systems, we find that the continuous repair work makes medication management both resilient and fragile.

2 Related Work

This study employs the conceptual framework of repair to analyze the healthcare practice of medication management, which is collaborative and cross-disciplinary. Medication is prescribed by physicians, while nurses are responsible

for dispensing and administration. In addition, pharmacists prepare medication for the wards and perform certain on-the-ward medication-related tasks. We start by reviewing existing research on repair to show how it can frame an analysis of medication management and its undergirding infrastructure. Following that, we give a brief overview of the two means of medication management analyzed in this study – medication reconciliation and closed-loop medication management.

2.1 Repair Work

Jackson (2014) posits that the world is, on the one hand, always almost falling apart and, on the other hand, continuously restored to working order. With the co-presence of these two opposing forces, stability is not a steady state but a process of constant *repair*: 'the subtle acts of care by which order and meaning in complex sociotechnical systems are maintained and transformed, human value is preserved and extended, and the complicated work of fitting to the varied circumstances of organizations, systems, and lives is accomplished' (Jackson 2014, p. 222). By this definition, repair is omnipresent and mostly taken for granted. It is a remarkable achievement but tends to recede into the background.

The concept of repair has its roots in the repair of material objects, such as cooling systems (Henke 2000), mobile phones (Gil 2024), and subway signs (Denis and Pontille 2019). Repairing these objects contributes directly to fashioning the product, or service, made by a group of actors. In the terms of Schmidt and Bannon (1992), the repair changes the state of their common field of work. Schmidt and Bannon (1992) distinguish between cooperative work and articulation work. Cooperative work contributes directly to fashioning a product or service; it changes the state of the involved actors' common field of work. In contrast, articulation work is extraneous to the activities that directly fashion the product; it involves the allocation, coordination, and scheduling necessary for the actors to work together as opposed to individually. In addition, repair happens in response to breakdowns, whereas articulation work is also about maintaining arrangements that prevent breakdowns (Corbin and Strauss 1993). Following these definitions, an act of repair is not articulation work. However, the concept of repair also applies beyond material objects. Like material objects, sociomaterial infrastructures are in constant need of repair to remain in working order. When they are applied to sociomaterial infrastructures, then repair and articulation become, as we will see, overlapping concepts. While we contend that repair and articulation are overlapping, but different, concepts, we recognize that others merge them into one. For example, Jackson (2014, p. 223) characterizes repair as 'a facet or form of articulation work (and vice versa)'.

Repair invokes the question 'Why did it break?' This question is central to the immediate concern of diagnosing and fixing the problem but also invites the larger question 'How can it be made to last?' Much of the recent interest in repair is associated with this second question because it entails a shift in focus

from new products toward sustainable products (e.g., Ahmed et al. 2015; Hector and Botero 2022; Jackson 2014). The discourses on design and innovation focus on devising new products. Thereby, these discourses tend to suggest replacing broken products with new ones and to devote little attention to repair, which is packed away in the maintenance phase at the end of the product life cycle. In contrast, research on repair puts maintenance center stage by offering insights into the competences, infrastructures, tools, and work involved in restoring broken things to working order. These insights include that current products are often designed not to be taken apart and fixed, thereby complicating or precluding repair (Ahmed et al. 2015). For example, product casings are glued together, components are fastened with proprietary screws, and access to documentation is restricted. The research on repair has also called attention to sustainability problems that relate to the global division of labor in product life cycles. For economic reasons, product maintenance and disposal are often outsourced to countries in the Global South and performed under unhealthy and unsafe conditions. A grave example is the dismantling and recycling of aging ocean vessels on beaches in South Asia (Crang 2010).

A number of people have repair as their profession, including mobile phone repairers (Gil 2024), subway maintenance workers (Denis and Pontille 2019), and technical support staff (Rosner and Ames 2014). However, repair refers more broadly to all activities that – upon breakdown – go into restoring the order of things. That is, repair is integral to all work, including that of healthcare professionals (Schubert 2019). It is integral to all work because breakdowns are part of normal work practices and, hence, repair is a requirement for normal work practices to take place. Henke (2000) goes as far as to suggest that skill may be defined as the ability to maintain the order of things, that is, to perform repair. This suggestion ties research on repair to that on order (e.g., Graham and Thrift 2007; Henke 2019; Wagner and Newell 2006). Order is socially constructed; it is negotiated among the actors in a collaboration and while it may be stable for now, it may also break down and require renegotiation – repair. That is, repair work is not restricted to the repair of tangible products. It involves 're-ordering people and their assumptions about a work setting, just as much as fixing the setting itself' (Henke 2000, p. 56). Many instances of repair blend social and material re-orderings.

Breakdowns in the order of things disclose the sociomaterial infrastructure that undergirds normal work practices. This infrastructure is normally unattended but becomes the focus of attention during repair, as also discussed in studies of infrastructural inversion (Bowker 1994; Simonsen et al. 2020). It is the infrastructure that must be repaired to be able to resume normal work practices. The mobile phone must be repaired to be able to resume normal communication practices; the turn-taking norms must be repaired to be able to resume normal conference practices; the heating system must be repaired to be able to resume normal office

practices; the rules for prioritizing patients for surgery must be repaired to be able to resume normal surgery-planning practices; and so forth. These instances of repair are often experienced as inconvenient or frustrating because they, unexpectedly, disrupt normal proceedings (Henke 2019). However, attending to the infrastructure is also an occasion for caring and learning. In this sense, repair work adds nuance to humans' relationships with one another and with technologies (Graham and Thrift 2007; Houston et al. 2016).

By adding nuance, repair differs from exact restoration: 'Successful or not, the repair work never brings back the initial (i.e., pre-breakdown) configuration' (Bovet and Strebel 2019, p. 90). First, the actors have learned something from the repair work. They have new sensitivities toward the infrastructure, and these sensitivities will influence their future use of it. Second, the objective of repair is to restore the infrastructure to working order. This objective does not equate exact restoration. Repair may quickly turn into improvement, partial fixes, or other kinds of evolution that restore the ability of the infrastructure to support normal work practices (Graham and Thrift 2007). In this way, repair fuses backward-looking restoration elements with forward-looking evolution elements. To stress the forward-looking elements, Henke and Botero (2022) use the term 'generative repair'. They identify three forms of generative repair: material workarounds, infrastructuring alliances, and relevance-building. While the first form blends social and material re-orderings, the two others are predominantly social and have a temporal perspective that extends beyond repairing a single breakdown. Using different labels, Mikalsen et al. (2018) describe three largely similar forms of repair: participation repair, process repair, and value-network repair.

Several studies point out that repair is improvisational (e.g., Mikalsen et al. 2018; Pink et al. 2019; Schubert 2019). It unfolds in response to the particulars of the situation, not according to a pre-specified plan. As shown by Suchman (2007), the actors must construct an understanding of the situation from within and, on that basis, devise a way forward. While the breakdown is normally apparent, it is not necessarily apparent how it can be fixed (e.g., Lejeune 2019; Tanweer et al. 2016). The reason for the breakdown may be unclear, the appropriate fix may be too time-consuming in the concrete situation, the available replacement parts may not be quite right, and so forth. Because the breakdown is a breakdown in a negotiated order, repair also involves power and politics, such as competing narratives about what is wrong, who is at fault, and how to proceed (Henke 2019; Jung et al. 2021). To restore order, the actors need to engage in renewed negotiation about the infrastructure of arrangements and alignments that undergirds their normal work practices. And they may disagree about the resulting level of repairedness (Jung et al. 2021). Typically, those benefiting from the existing infrastructure will prefer a repair that comes close to an exact restoration, while those critical of this infrastructure will be more likely to see the breakdown as an occasion for change.

In relation to medical work, Schubert (2019) describes how physicians and nurses routinely deal with breakdowns to maintain stable medical practices. Importantly, medical practices are not put on hold while the breakdowns are fixed. Instead, repair – in the form of adaptations, improvisations, and so forth – is integral to an orderly course of events because medical work involves many contingencies and uncertainties. The sources of these contingencies and uncertainties include diagnoses, treatments, clinical documentation, technical equipment, organizational procedures, tensions between standardization and individual care, interferences between different kinds of work, and patients' activities outside the hospital (Schubert 2019; Strauss et al. 1985). Some repair work follows simple and practical recipes that are sufficiently recurrent to be quasi routines. When this is not the case, repair work may be held up by hesitation to step outside of formal procedures. For example, Schubert (2019) describes a situation where a surgical team hesitated to proceed because nobody wanted to assume responsibility for performing a non-standard, but effective, workaround. The team was on the verge of discontinuing the operation when a senior surgeon entered the operating room and, after some deliberation, approved the workaround. Because medical work is critically dependent on recorded patient data, some breakdowns and repairs arise from encountering anomalies in the data. Medication management is a case in point. In a non-healthcare study, Tanweer et al. (2016) show how interrogation of the data is central to understanding and repairing such anomalies. The interrogations alternated between zooming out to see patterns and zooming in to sort and sift details.

2.2 Medication Management

Medication management spans the activities from a medication is prescribed or requisitioned until it is dispensed to the patient or discarded. It involves, among other things, documenting a patient's medication (e.g., Zhang et al. 2022), coordinating clinicians' medication-related activities (e.g., Reddy et al. 2001), and designing electronic medication-management systems (e.g., Andersen 2013). In this paper, we focus on two means of ensuring the quality of medication management: medication reconciliation and closed-loop medication management. Both of them serve the purpose of avoiding medication errors, and both of them do so by bolstering the link between a patient's prescribed and actual medication. In addition, both of them involve large amounts of what Verdezoto et al. (2021, p. 1) term 'the invisible work of maintenance'. While medication reconciliation targets the early stage of medication management, closed-loop medication management targets its later stages.

Medication reconciliation is 'the process of determining the most accurate list of medications the patient is taking' (Flanagan 2018, p. 14). An inaccurate list introduces inadvertent changes in the patient's medication. Such changes are a risk to patient safety and particularly likely at transitions in care, for

example from home to hospital. In hospitals, medication reconciliation is most important at admission but should also be considered at ward transfers internal to the hospital and at discharge (Fernandes and Shojania 2012). If medication reconciliation is not performed at admission, then all medication decisions made between admission and reconciliation must be reevaluated once reconciliation has taken place. The added work is an extra reason for performing reconciliation at admission. However, medication reconciliation is itself a time-consuming process and not always prioritized at admission, due to more urgent admission activities or general busyness (Pevnick et al. 2016). When medication reconciliation is performed at hospital admission and supported by an electronic system, then Mekonnen et al. (2016) find that it results in a significant 45% reduction in the proportion of medications with unintentional discrepancies.

Closed-loop medication management is the 'end-to-end electronic medication management with seamless flow of information along the process' (Agrawal 2009, p. 681). Typical components in this process are electronic prescribing, dosage-packaged medication, and barcoded patient identification. These components reflect a focus on the process from prescribing, through dispensing, to administration of the medication. Medication-related activities prior to prescription (e.g., drug manufacturing) and after administration (e.g., prescription renewal) are mostly considered external to the loop. Franklin et al. (2007) find that closed-loop medication management significantly reduces prescribing errors and administration errors but at the cost of increased time spent on medication-related tasks. That is, the improvement is not simply caused by the electronic support but also involves committing additional human resources to medication management. The increase in the amount of time spent on medication-related tasks may be as large as 45% after closed-loop medication management has been in operation for six months and work practices presumably have stabilized (Bingham et al. 2021).

3 Method

Our empirical work followed an interpretive research approach (Klein and Myers 1999; Walsham 2006). This meant that the studied phenomenon – medication management – was considered from multiple perspectives. Specifically, we included the perspectives of the different professional groups involved in medication management at hospitals. All participants orally consented to take part.

3.1 Settings

The two case studies were conducted at two hospitals in Norway. Both hospitals provided specialist healthcare financed by the government via general

taxes, rather than by the patients via medical insurance. Medication reconciliation was studied at Narvik Hospital, an 86-bed hospital serving a population of about 30,000 in Northern Norway. This hospital had been in operation for decades and its infrastructure for medication management had evolved throughout this period. Closed-loop medication management was studied at Kalnes Hospital, a 418-bed hospital serving a population of about 300,000 in Southern Norway. This hospital opened to patients in 2015 with state-of-the-art solutions for, among other things, medication management. In addition to electronic solutions internal to each hospital, both hospitals imported and exported selected patient information through national components for exchanging this information across healthcare institutions. The information exchanged through these components included, as our analysis will show, information for medication management.

3.2 Procedure

At Narvik Hospital, we interviewed a physician, two nurses, and a pharmacist. We also interviewed a nurse at a municipal health center collaborating closely with Narvik Hospital. The overall topic of the interviews was medication management, but the interviewees emphasized medication reconciliation. We probed them to elaborate on this specific topic, including how it involved collaboration with entities external to the hospital. The interviews were supplemented with a one-day workshop about the sociotechnical challenges of medication management. The workshop was attended by healthcare professionals from Narvik Hospital and another hospital.

At Kalnes Hospital, we interviewed two physicians, three nurses, and two pharmacists. The physicians and nurses were from different wards; the pharmacists were from the hospital pharmacy. All interviews were about how closed-loop medication management was implemented at the hospital. We asked about the equipment in use as well as the associated work practices. The interviews were supplemented with three days of observation. The observation sessions covered how medication was repackaged at the hospital pharmacy and how it was stored, prescribed, dispensed, and administered to patients at three hospital wards. We also read the standard operating procedures concerning closed-loop medication management.

All interviews lasted about an hour. They were conducted in an open-ended manner guided by a small set of questions prepared ahead of each interview. We encouraged the interviewees to provide rich descriptions of their work practices, including the artifacts used in performing these practices and the rationale for performing them the way they did. All interviews were audio-recorded and transcribed for analysis. The workshop and observation sessions were documented in field notes.

3.3 Data Analysis

The guiding principle in our analysis was Klein and Myers's (1999) tenet that all human understanding of a phenomenon is achieved by iterating between the interdependent meaning of its parts and the phenomenon as a whole. In the early stages of the study, this principle involved iterating between interviews and analysis. Insights from the first interviews (and the first supplementary materials) laid the foundation for the subsequent ones and were intentionally used in preparing each new interview. We also iterated among interviewees with different professional backgrounds to reach a fuller understanding of medication management. For example, our interprofessional approach revealed differences in the level of repairedness pursued by different groups. In both case studies, we interviewed physicians, nurses, as well as pharmacists. Furthermore, the study at Kalnes Hospital also involved presenting preliminary study findings to clinicians and pharmacists, thereby getting feedback from practice. This feedback included that the participating practitioners engaged in discussions with one another about the meaning and implications of our findings, thereby enriching our own understanding of them. The workshop in the study at Narvik Hospital provided somewhat similar possibilities for us to learn from discussions among healthcare professionals with different perspectives on medication management.

After all interviews had been conducted, we read the interview transcripts to become sensitized to their contents. We had read several of the transcripts before but this time we read them in the context of the full set of materials. The analysis proceeded by iteratively reading and annotating the transcripts with codes generated in a ground-up manner. Initially, we applied open coding. That is, the codes were phrases used by the interviewees or, in the absence thereof, short descriptive phrases. These codes were at different levels of abstraction, ranging from names of consulted systems (e.g., 'the Central Prescription Database') to pursued values (e.g., 'the importance of talking with the patient about the medication they actually use'). Therefore, some codes subsumed others. Other codes were interlinked in other ways. The open coding gradually evolved into a search for themes that linked codes together. These themes revolved around the sociomaterial infrastructure that undergirded medication management (e.g., 'data fragmentation', 'prescription versus actual use', 'medication repackaging', and 'workarounds'). An element that recurred across the themes was the constant work entailed in making the infrastructure work – in spite of the substantial resources that had been invested in devising it. Inspired by the literature (e.g., Jackson 2014), we conceptualized this constant work as repair.

With repair as our conceptual framework, we revisited the transcripts to verify that this framework accorded with the interview statements that induced major codes and themes. We found a good match and organized our analysis around the repair framework. Specifically, its focus on how actors – in improvisational or quasi-routinized ways – restore things to working order proved useful

in understanding medication reconciliation and closed-loop medication management. We also identified and excluded themes that fell outside of the repair framework, such as the special precautions that surrounded the dispensing and administration of classified drugs. In total, our analysis combined inductive coding and deductive conceptualization to bring out the specifics of our empirical material.

4 Findings

To convey the content and extent of the repair work involved in medication management, we provide rich descriptions of the two practices studied. Both medication reconciliation and closed-loop medication management are described from the different perspectives of first the physician, then the pharmacist, and finally the nurse.

4.1 Medication Reconciliation

When a patient is admitted to Narvik Hospital, the reconciliation of the patient's medication becomes a task for the *physician* attending the patient. Depending on the complexity of the patient's condition, the process of medication reconciliation takes anywhere from a few minutes to half an hour or more. Initially, the physician uses several electronic information sources to obtain an overview:

> First you access the patient in DIPS [i.e., the hospital EHR]. However, you cannot be certain that all medication has been retrieved from the Central Prescription Database. So, you have to open that and copy whatever is missing in DIPS from the Central Prescription Database into DIPS. When you have done that, you have a list with the medications that are in DIPS and the Central Prescription Database. There may be items that are duplicated or the same drug; you need to remove such items. So, you need to work your way through the list. In addition, we check the Summary Care Record because the patient may have acquired medication that is neither in the Central Prescription Database nor in DIPS. (physician, Narvik Hospital)

The physician starts by looking up the patient in the electronic health record (EHR) of the hospital but knows that the medication list in the EHR is not up to date. It is broken from the outset and must be repaired. It is broken because the EHR is only used during hospital stays and has not been updated since the patient's last hospital contact. To repair the medication list, the physician accesses the Central Prescription Database, which is a nation-wide system with information about dispensed medications for a patient's active prescriptions. However,

the Central Prescription Database may also be out of date and, in that sense, broken and in need of repair. Therefore, the physician checks the information about the patient's medication in the Summary Care Record, which is another nationwide system. It may contain information about medication that is not listed in the Central Prescription Database, for example because the patient acquired it from a pharmacy while abroad. The medication lists in the three systems are likely to include duplicates that need to be manually identified and removed. The physician must also consider whether the medication is in current use:

> You also need to reconcile whether it is medication they still use or old prescriptions, so you check when they acquired it. If it is something they acquired last week, then they are most likely still using it. You need to apply some logical thinking. (physician, Narvik Hospital)

Old prescriptions may no longer be valid indicators of the patient's current medication. New prescriptions probably are. It often comes down to a professional assessment, including a close reading of the prescriptions. For example, medications such as antibiotics may be prescribed for regular use or for as-needed use, thereby necessitating further deliberation and the use of common sense to sort out whether the patient currently takes them. Many frail and elderly patients have a sizable number of prescriptions, and the physician may remain uncertain about how to reconcile them into a consolidated list. For those patients, the physician often solicits additional information to complete the repair of their medication list:

> If they are receiving home care, then you can get a complete list [of their medication] from the home-care service. In those cases, you use the PLO system to send a message to the municipality and then you get a message back from the home-care service with a complete list. That list will contain the medication the patient actually uses, so if something on this list does not match the information from the Central Prescription Database, then we trust the list acquired through the PLO system because they update it more often. It is the same with nursing homes. You get a list from them because you cannot be certain that the Central Prescription Database and the Summary Care Record are up to date for nursing-home patients. So, you obtain a list from a nursing-home physician who will have a complete list of what medication they are currently using. (physician, Narvik Hospital)

Many frail and elderly patients receive home care or live in nursing homes. In Norway, home care and nursing homes are part of municipal healthcare and thus administratively separate from the hospitals. While an electronic messaging system (the PLO system) supports the exchange of information between

hospitals and municipal healthcare, the messages are answered by people. The physician does not have direct access to the electronic records in home care and nursing homes. By contacting home care and nursing homes, the physician extends the scope of the repair work from a search in multiple systems to a collaboration among multiple people, that is, the repair involves articulation work. The staff in the home-care service or nursing home interacted with the patient right up to the transition to hospital and thus, have up-to-date information about the patient's medication. Therefore, the physician is inclined to trust the information from home care and nursing homes if there is a mismatch between this information and that in the Central Prescription Database. Specifically, the nursing homes store medication information in their internal EHR only, thereby rendering the information in the Central Prescription Database out of date. It tends to take longer to acquire information through the electronic messaging system than by accessing the Central Prescription Database and the Summary Care Record. In urgent cases, the physician phones the home-care service or nursing home instead.

The next step is to talk with the patient to double-check everything. Though this step is important, it is often postponed because other treatment activities take precedence or the patient is too weak. When performed, the patient may comment on a medication by saying: 'I have it, but I don't really use it.' Then, the physician removes this item from the list. For each medication added to or removed from the patient's medication list, the physician must state the reason for the change in the EHR. These reasons provide documentation of the repair work. When the physician has repaired the medication list in the EHR, the list is printed and becomes the basis for future decisions about the patient's medication:

> You need to reconcile the medication list in DIPS with all the information you acquire externally to see whether it matches. It is only when you have done all that that you have a reconciled list that you can print and sign. (physician, Narvik Hospital)

The printed medication list is known as the paper chart. It is the authoritative record of the patients' medication during their admission. The physician's signature on the paper chart indicates that medication reconciliation has been performed. However, repair work continues. The additional repair work serves to double-check the medication reconciliation and achieve a higher level of repairedness. To this end, medication reconciliation is continued by the *pharmacist* and thereby becomes an interprofessional process. Pharmacists are specialists in medication – its preparation, its effects, and its safe and effective use. They are gradually assuming a more patient-facing role in Norwegian hospitals. The pharmacist starts from the paper chart and uses it to go through the patient's medication with the patient:

> I do a bedside walkthrough of the medication list with the individual patient. That is, I talk with the patients to determine what medication they actually use because the list does not always match what they actually use. (pharmacist, Narvik Hospital)

The pharmacist's main concern is to determine what medication the patient actually uses. Therefore, talking with the patient is essential. In contrast, the physician may have had the opportunity to talk with the patient about medication use but has mostly relied on sources with information about the patient's prescriptions. The pharmacist finds that 'There is almost always something that does not match.' Fortunately, it is usually small things that are not on the list, such as some non-prescription medication or small dosage discrepancies. Repairing these issues increases the quality of the medication reconciliation but does not have a large effect on patient treatment and outcomes. Severe issues are rarely discovered, but it happens every now and then. For example, the pharmacist recounts a situation with a patient who arrived in the emergency department in a bad state and could not be asked about his medication:

> He had a medication list in his wallet, and this list was taken as a starting point. Later, it turned out that the list was three years old and not current. Several drugs that had been discontinued were now suddenly restarted. So, the initial treatment was completely off compared to what it should have been. (pharmacist, Narvik Hospital)

It is not easy for the pharmacist to obtain accurate information from patients about how they use their medication. Even if they know how they are supposed to use it, many patients find their own way of using it, do not adhere strictly to prescribed dosages, or make day-to-day changes depending on how well or ill they feel. The pharmacist probes the patient for these details, partly by explaining that they are more useful for ensuring correct treatment and medication during the hospital stay than information about how the patient is supposed to use the medication. However, some patients are too frail to handle their medication themselves and do not know exactly what medication they use. In these cases, it may be difficult to ascertain who can provide the most accurate information. The pharmacist might contact the home-care service or the patient's nursing home for further information, thereby continuing the repair work by returning to sources the physician has probably already consulted. The renewed contact serves to double-check by providing an opportunity for articulating additional detail.

On the basis of all the information obtained, the pharmacist determines what changes are necessary to make the medication list accurate and assesses whether the patient's treatment could be improved by adjusting drugs or dosages. Then, the pharmacist writes a note in the EHR about these repairs and, in urgent cases,

also informs the physician orally. It is only the physicians who are authorized to change the patients' medication, so the pharmacist's repair work ends by informing the physician. Generally, the physician acts on this information and updates the paper chart, at least regarding new information about what medication the patient actually uses:

> Regarding the reconciliation of what the patient actually used when admitted, they [i.e., the physicians] accept it. When I have discovered that it is like this rather than like that, then they don't question it. What we might discuss is the subsequent treatment. If I find that the patient uses one medication and the guidelines say they should be using another or a different dose, then we might discuss a bit. It is the physician who has the final say. So, I might propose something and they may decide to do something else. (pharmacist, Narvik Hospital)

The *nurses* administer medication on the basis of the paper chart. If a medication is not on the paper chart with the physician's signature, then they will not administer it to the patient. Thus, it is important that omissions and other inaccuracies in the paper chart are repaired quickly. The nurses' use of the paper chart involves additional repair work, mostly about the correct interpretation of the chart information. For example, some physicians indicate doses in milligrams when they add new prescriptions on the paper chart, while others indicate doses in number of tablets. The nurse must carefully and repeatedly convert back and forth between these two dosage representations to repair the inconsistent prescription format. A nurse comments: 'When the representations differ, you kind of have to retune your head. In the worst cases, it switches from line to line [on the same paper chart].' Repair is also needed when prescriptions are ambiguous:

> It is challenging if a patient is to have a total dose of 150 milligrams of Selo-Zok and the physician chooses – because they have used the Central Prescription Database – to write one line with "100 mg x 2, 1 morning and 1 evening" and another line with "50 mg x 1". Then you are left wondering what to give the patient. Does it for example mean 150 mg in the morning and 100 mg in the evening? (nurse, Narvik Hospital)

In this case there are two prescriptions ('lines') for the same medication and it is unclear how they should be merged into a coherent understanding of the intended dose. To arrive at a coherent understanding, the nurse needs to consult the physician who prescribed the medication so that they can engage in articulation work about the intended dose. If that physician is not currently on duty, this cannot be done immediately. Until the prescribing physician has been consulted, the nurse will typically not administer the medication, thereby causing

interference between administering and repair. At each medication round, the nurse has the opportunity to talk with the patient about the medication. These conversations inform the patient, but they are also a final step in the medication-reconciliation process. Sometimes, a patient will say 'But I use a different dosage' and further repair is needed.

4.2 Closed-loop Medication Management

At Kalnes Hospital, the *physicians* mainly contend with the closed medication loop when they need to prescribe a medication that is not registered in the database of the electronic medical record (EMR). Ideally, all medication should be registered in the database because that would keep the medication loop more closed. Currently, the database does not contain all medication. The physicians repair these incompletenesses by entering a prescription for a medication with the catch-all name 'X medication' and then articulate the actual name and the dose in a free-text note:

> For medications that are not registered, we use 'X medication.' Then you have to specify everything manually. So, you write a note indicating the name of the medication and the dosage. Normally, you also write how the medication is to be administered. (neurology physician, Kalnes Hospital)

With this repair, the intended prescription has been recorded, even if only in free text. However, the repair precludes closed-loop management for these prescriptions because it is not possible for the EMR to match 'X medication' to subsequently dispensed medication dosages. The neurology physician finds that 'it is not a problem' to use this repair for unregistered medication; it gets the job done. In contrast, the other interviewed physician (from the geriatric department) finds that 'it is an absolutely terrible thing'; the achieved level of repairedness is simply too low.

In the hospital *pharmacy*, the closed medication loop involves nonstop repair of the packaging in which medication is delivered from drug manufacturers. Closed-loop medication management requires that each tablet and other medication unit has a barcode. This barcode must be scanned when the medication is dispensed to enable the EMR to check the dispensed medication and dose against the prescription recorded in the EMR. However, few drugs have single-unit barcodes when delivered from the drug manufacturers. Therefore, the hospital pharmacy repackages the medication to break it up into single units and barcode each unit. This repair work is time-consuming. For example, some tablets are delivered in blister wrappings; removing this protection considerably shortens the shelf-life of the tablets. The pharmacy staff needs to cut around each tablet with a pair of scissors while taking care to retain the blister and, at the same time, making each blister-wrapped tablet sufficiently small to fit in the machine for packaging and

barcoding them. Other types of medication, such as asthma inhalers and insulin pens, cannot be repackaged into single-dosage units. Because repair is impossible, these medications have to be excluded from the closed medication loop.

The interviewed pharmacist states that it is a challenge 'to satisfy the demand for repackaging.' Currently, they do not have the resources to repackage everything. Instead, decisions about what to repackage are integral to the repair work. These decisions are the result of hospital-level deliberations, thereby extending the scope of the repair work beyond the individual pharmacist. Relatedly, the pharmacists' repair work also involves considerable double-checking and documentation to avoid errors and comply with the strict regulations that govern pharmacy work. As a result, the pharmacists' repair work is not just restoring order to the closed medication loop; the repair work itself is an orderly performance. This order is manifested in the structured repackaging process, in the packaging-and-barcoding machine, and in the documentation of the repackaging activities.

The repackaged medication is distributed to the hospital departments, which keep it in their medication rooms until it is dispensed by the *nurses* and administered to patients. To dispense a patient's medication, the nurse walks through the patient's prescriptions in the EMR, collects each medication from the shelves in the medication room, and stores it in the trolley that is used for transporting medication to the patients. The trolley has a separate drawer for each currently admitted patient. For each medication, the nurse must scan the barcode on the medication and the barcode on the patient's drawer. Whenever the medication prescribed for a patient is not available in the medication room, repair work is needed to obtain the prescribed medication. This work may involve inspecting the medication available, seeking information online, and contacting other departments:

> A patient has a prescription for 5 mg of Crestor. The department stores only 10 mg Crestor tablets. The nurse opens the blister wrapped around such a tablet to see whether it has a line indicating that it can safely be divided into halves. There is no such line. The nurse looks up the tablet online and learns that it must be swallowed whole. Then, the nurse checks in Delta [i.e., the system that lists the medication each department receives from the hospital pharmacy] whether another department stores Crestor in 5 mg tablets. One of them does, and the nurse phones to get a tablet from there. (fieldnote, Kalnes Hospital)

In this situation, another department completes the repair by providing the prescribed medication. In other situations, the prescribed medication dose can be safely obtained by dividing a double-dose tablet into halves. However, the

resulting half tablet has no barcode. To complete these repairs, the nurse needs to print one:

> A tablet has been divided into halves. The nurse prints a new barcode for this half tablet and attaches it to a plastic bag containing half the tablet. (fieldnote, Kalnes Hospital)

Repair work is also needed when the prescribed medication is available, but the pharmacy has not had the resources to repackage it into individually barcoded single units. Without a barcode, the dispensed medication cannot be electronically matched against the prescription in the EMR. Instead, the nurse must make the match and, thereby, compensate for the missing single-unit barcode. However, the prescriptions specify medication by its generic name. Multiple vendors may manufacture the medication, each using a vendor-specific product name. The product in store at the departments depends on which vendor the hospital pharmacy currently uses. Thus, the nurses' repair work involves translating the generic names into product names:

> Sometimes, the name in the EMR is different from what the tablet is called. Then you need to know the product name or to look it up in the medication catalog that we have on the phone. (nurse, surgical department, Kalnes Hospital)

For some recurrent types of missing barcodes, the nurses have developed workarounds. For example, the nurses know that tablets are often not individually wrapped and barcoded and, therefore, keep the last one of an equivalent tablet in a barcoded wrapping. They then scan the barcode of this tablet but dispense a tablet from a multi-tablet package. This workaround repairs the problem of the missing barcode while freeing the nurses from the work of printing a new barcode. However, the level of repairedness is reduced because the dispensed tablet and the scanned tablet are not the same. A similar workaround had previously been in place for antibiotics, which are stored in another room because the medication room is too small to store them in there:

> Previously, they had a list in the medication room with the various antibiotics they have in stock. After the name of the antibiotic there was a barcode they could scan. This way, they could complete the scanning while in the medication room. Afterwards, they would collect the antibiotics. (fieldnote, Kalnes Hospital)

This workaround has, however, been discontinued because it involved collecting the antibiotics from the other room after completing the work in the

medication room for all patients, thereby increasing the risk of inadvertently administering an antibiotic to the wrong patient. Now the nurses walk back and forth between the two rooms to collect the antibiotics for scanning; the level of repairedness has increased.

When the nurses administer the medication, they wheel the trolley to the patient room, scan the barcode on the patient's wristband, and scan the barcode on each medication in the drawer for that patient. Instead of scanning each medication, they can also manually mark them as administered in the EMR. The nurses tend to prefer the manual process because it is faster than scanning. A nurse says that scanning is so slow that 'You will never finish.' However, irrespective of whether the nurses document the administration of the medication manually or by scanning it, a lot of their attention is tied to the computer. They worry that the patients may not feel seen:

> Before [i.e., before the introduction of closed-loop medication management], you might go to the patient with the medication and tell what is what. Then check if the patient agreed and, if so, administer it. Now, we experience that we look more at the computer screen and are more concerned with making that work than with communicating with the patient. (nurse, neurology department, Kalnes Hospital)

As a result, the closed medication loop creates a need for yet another kind of repair work. This additional repair work is not directed at keeping the medication loop closed but at repairing the nurses' communication with the patients.

5 Discussion

Hospitals devote substantial resources to medication management because it is critical to patient safety and treatment. Some of these resources are spent devising systems and procedures for the orderly conduct of medication management; others go into repairing the breakdowns in these systems and procedures. We have analyzed the repair work involved in medication reconciliation and closed-loop medication management. The following discussion of this repair work is structured around the issues that bring repair about, the qualities that characterize repair, and the implications of repair.

5.1 Issues That Bring Repair About

The immediate cause of an act of repair is a breakdown. Aside from this immediate cause, we want to emphasize three issues that bring repair about. First, a breakdown in the order of things presupposes an installed base of norms, standards, systems, and other schemes that institute order. Without an instituted order,

nothing would be out of order and, hence, in need of repair (Jackson 2014). It is, for example, the norm and benefits of a reconciled medication list that necessitate the repair of the fragmented medication information available when a patient is admitted at Narvik Hospital. Apart from instituting the expected order, the installed base also scaffolds the repair work by providing some of the means for restoring order. Examples of these means include the Summary Care Record, the pharmacists' bedside walkthrough of a patient's medication, and the packaging-and-barcoding machine in the pharmacy. The incorporation of such means in the installed base shows that repair work is recognized as an activity that is central to maintaining stable performance – to keeping the infrastructure in working order (Hanseth and Braa 2001).

Second, the need for repair increases with the boldness of the instituted order. A bold order that sets high standards will require an elaborate sociomaterial infrastructure to undergird the multiple activities involved in performing according to these standards. With increasing elaboration, the possibilities for breakdown also increase. Closed-loop medication management is a case in point. Its bold aim of barcoding each medication unit to keep track of it presents a series of challenges at Kalnes Hospital, especially for the pharmacists and nurses. These challenges lead to lots of repair work, which is often either cumbersome or at a diminished level of repairedness. Such a tradeoff between effort and quality is well-known from studies of workarounds (Cabitza and Simone 2013). It shows that repairs, especially repairs of bold orders, must negotiate the goal of restoring order to a highly set standard (e.g., the closed medication loop) against that of restoring it sufficiently to complete the current activity (e.g., the dispensing of a patient's medication). Jung et al. (2021) show that the attained level of repairedness is also negotiated when the repaired order is less bold than closed-loop medication management.

Third, imperfections in the infrastructure that undergirds an order necessitate repair. In the two studied cases, these imperfections include fragmented data, partially integrated systems, slips in colleagues' work, other treatment activities taking precedence over medication management, prescribed medication that is not taken, medication supplies that are not single-unit packaged, and so forth. One source of such imperfections is that infrastructures evolve over time to accommodate uses for which they were not originally designed (Star and Ruhleder 1996). These evolutions are gradual and piecemeal, thereby leaving cracks and imperfections in how the infrastructure supports its users' practices. For example, medication vendors are only gradually starting to supply tablets in single-unit packages, a demand that is fairly recent. Another source of imperfections is local particulars that stand in the way of optimal practices. Something as basic as the size of the medication room causes suboptimal practices and repair work at Kalnes Hospital because antibiotics must be stored in another room and therefore are cumbersome for the nurses to scan when they dispense medication. The

import of local particulars on repair practices has received considerable attention (e.g., Suchman 2007).

5.2 Qualities of Repair Work

The object of many of the studied repair acts – especially in closed-loop medication management – is a breakdown in the field of work, not a breakdown in the allocation, coordination, or scheduling of collaborating actors' activities. The direct contribution of these repairs to fashioning patient treatment is evident throughout the analysis. For example, the physicians rectify newly admitted patients' medication lists to continue any ongoing treatment, the pharmacists repackage medication into single units, and the nurses divide or solicit tablets when the right dosage is not available in the medication room. These repair acts show the difference between repair and articulation work, which is about the allocation, coordination, and scheduling necessary for actors to work together (Schmidt and Bannon 1992). However, there are also repair acts – mainly in medication reconciliation – that involve articulation work. For example, the physicians sometimes contact home care and nursing homes to discuss and clarify what medication a patient is currently taking. While medication reconciliation is concretely about repairing medication lists that are out of date, the repairs are largely accomplished through a process of reaching agreement among the actors involved in managing the patients' medication. That is, articulation work is a common mode of repair in medication reconciliation. In contrast, closed-loop medication management is to a larger extent, but not exclusively, repaired by repackaging and otherwise handling material objects in the field of work. This handling is not articulation work.

In an analysis of repair work in relation to personal tracking devices, Hansen (2024, p. 209) contends that 'the concept of articulation work contributes to nuancing exactly this: the specific type of repair work that is taking place and its significance.' We concur but with the qualification that articulation work can only nuance the acts of repair that involve the allocation, coordination, and scheduling necessary for actors to work together. To elaborate this qualification, we refer to how Strauss et al. (1985) divide the total organization of work done in healthcare over the course of a patient's illness into articulation work, comfort work, machine work, safety work, sentimental work, and patients' work. Depending on the act of repair, one or another of these kinds of work may contribute to nuancing the repair work and its significance. As our analysis shows, hospital staff must constantly engage in repairing the infrastructure that is in place to support medication management. We contend that treating repair and articulation as overlapping, but different, maintains conceptual and analytic clarity. Beyond distinguishing repair from articulation, we point to three further qualities of repair work: Our analysis shows that medication management is collaborative, continuous, and critical repair work.

First, the repair work is *collaborative* (see also, Ahmed et al. 2015; Jung et al. 2021; Mikalsen et al. 2018). It involves physicians, pharmacists, and nurses; it is neither performed by a single person, nor assigned to a group of designated repairers. Thereby, the repair involved in medication management differs from the repair of, for instance, mobile phones, which is delegated to a group with special repair qualifications (Gil 2024). To some extent, the physicians, pharmacists, and nurses repair different parts of medication management. For example, the physicians prescribe 'X medication' to repair incompletenesses in the EMR database, while the pharmacy repackages medication into single units. However, the actors also add to repairs initiated by other actors to increase the level of repairedness. For example, the pharmacists do a bedside medication walkthrough that complements the physicians' medication reconciliation, and the nurses repackage and barcode medication that has not been single-unit barcoded by the pharmacy.

Second, the repair work is *continuous* (see also, Graham and Thrift 2007; Jackson 2014; Strebel et al. 2019). It is continuous because the repairs merely restore the individual instance of medication management to working order. For example, reconciling a patient's medication merely makes the medication list accurate for now. If the patient is readmitted at a later point in time, the medication list must be reconciled anew because the issues that made medication reconciliation necessary the first time have remained in effect. Similarly, the issues that make drug manufacturers deliver medication in multi-unit packages are not solved by the repackaging in the hospital pharmacy. On the contrary, the repackaging replaces – one medication package at a time – a process that would be more efficient if the medication was packaged and delivered in single-unit packages by the manufacturers. Because the issues persist, the sociomaterial infrastructure that undergirds the clinicians' practices remains imperfect. As a result, order continues to break down and 'repairs cease to be exceptions to a given norm, but rather become its underlying mechanisms' (Schubert 2019, p. 37). With a continuous need for repair, it becomes an integral aspect of work. Medication reconciliation and closed-loop medication management are, to a considerable extent, acts of repair.

Third, the repair work is *critical* (see also, Henke 2000; Schubert 2019; Tanweer et al. 2016). It is critical in the double sense that repair work is a requirement for quality medication management and that quality repair work is also a requirement. The former is evident throughout our analysis. Without repair, medication management would break down and patients would be at increased risk of suffering harm. The latter relates to the repeated considerations about whether the level of repairedness is sufficient. In some cases, the clinicians appear to disagree somewhat about the level required. For example, the pharmacists' bedside walkthrough to reconcile a patient's medication aims to double-check and improve the level of repairedness attained by the physician. In other cases, the hospitals have terminated repair practices that were deemed insufficient. For example, the

practice of keeping a list with barcodes for antibiotics in the medication room has been discontinued to reduce the risk of scanning an antibiotic for a patient but, inadvertently, dispensing another antibiotic or administering it to another patient. Each individual act of repair attains one out of multiple possible levels of repairedness (Jung et al. 2021). That is, repairs are non-binary; the required level is collaboratively determined and dependent on contextual factors, such as the implementation of a closed medication loop.

5.3 Implications

The overarching implication of bringing out the repair work involved in medication management is a shift in focus from the order of things to the work involved in maintaining this order. More specifically, we see eight implications of this repair work.

First, the continuous repair work has the double effect of making medication management both resilient and fragile. On the one hand, the repair work keeps the medication-management infrastructure in working order across a wide range of situations, each with its distinctive features and individual quirks. On the other hand, the repair work is improvisational and susceptible to slips, oversights, and other human errors. It is by being situated rather than preplanned that repair work makes medication management both resilient and fragile. While most repairs are at a high level of repairedness, some are not.

Second, some breakdowns recur at a frequency that routinize the repair work. There are, for example, large elements of routine in the physicians' medication reconciliation and the pharmacists' tablet repackaging. This routinization stands in contrast to the frequent description of repair as improvisational (e.g., Mikalsen et al. 2018; Schubert 2019). Routinized repair emphasizes that some breakdowns are anticipated to the extent of being unsurprising and handled in a standardized manner. Such routinized repair is an occasion for extending infrastructures with functionality supporting the repair work. In Norway, such extension is underway for medication reconciliation (Ellingsen et al. 2024).

Third, routinized and improvisational repair emphasize different aspects of repair. Routinized repair is recurrent to the extent of almost ceasing to be a deviation from the orderly conduct of work. It foregrounds that repair work is continuous but may background that the working order has been broken. In contrast, each act of improvisational repair concerns the features of the individual breakdown (e.g., Henke 2000). Thereby, it foregrounds the situated ways in which things are out of order but may background the frequency of repair work. Together routinized and improvisational repair are key to situating action to the conditions under which it unfolds.

Fourth, repair work is frequently exported from the early toward the later stages of medication management. Such an export happens when breakdowns are initially repaired to an insufficient level of repairedness or not repaired at all. For example, ambiguity in the physicians' reconciled medication prescriptions

creates subsequent repair work for the nurses. Notably, these exported repairs occur in a domain where the actors are attuned to the importance of maintaining high standards because errors may have severe adverse consequences for patients. Exported repair burdens those responsible for the later stages of a process with extra work. They will often be staff lower in the organizational hierarchy, such as nurses. In addition, Sambasivan et al. (2021) note a compounding effect of exporting work to later in a process. This compounding effect means that exporting a repair tends to amplify its potential consequences, thereby multiplying the work required to repair it later and, at the same time, emphasizing the importance of sufficient levels of repairedness at this later stage.

Fifth, the repair of complex and fragmented data involves exploring and gaining an overview of the data. For example, the data for long-term patients with chronic conditions may be too voluminous or too messy for relations among the elements to be readily discernable, thereby delaying the physician in reaching conclusions and making repairs (Torsvik et al. 2018). To support improvisational repair, functionality for performing such repairs should provide for exploration, such as by zooming out to see patterns and zooming in to inspect details (Tanweer et al. 2016). To support routinized repair, more task-specific functionality and procedures may be possible.

Sixth, the amount of repair work appears to be increasing. With a growing number of increasingly complex technologies in use at work (and outside of work), the possibilities of breakdown and, hence, the need for repair also increase (Graham and Thrift 2007). Most efforts to improve tasks through automation leave some unautomated subtasks, some unhandled special cases, or some unstable system integrations. The introduction of closed-loop medication management at Kalnes Hospital is an illustrative example. It aims to do away with improvisation and error-prone routines, but in effect comes with considerable repair work that partially undermines this aim.

Seventh, repair provides a concept for analyzing how actors restore things to working order after a breakdown. The breakdown may involve any aspect of the work done over the course of a patient's illness. For breakdowns in the allocation, coordination, and scheduling of cooperative activities, the concept of articulation work provides a well-established means of analyzing and adding nuance to the repair work. Other breakdowns are repaired by fashioning the product or service directly and, thus, do not involve articulation work (Schmidt and Bannon 1992). In this way, repair contributes to distinguishing analytically among different forms of breakdown. We believe that such distinctions will help sharpen analyses and facilitate conceptual development.

Eighth, the concept of repair contributes to understanding how work is accomplished but also to recognizing why it can be stressful. On the one hand, repair celebrates our ability to situated action, to continuously restoring things to working order when technologies, procedures, or collaborations break down. On the

other hand, repair reveals that physicians reconcile medication lists again and again, that pharmacists repackage medication again and again, that nurses convert back and forth between dosage representations again and again, and so forth. They need to repair the same types of breakdowns again and again because their repairs merely restore the individual breakdown instance to working order. Such work conditions contribute to fatigue and a sense of stress (Stana and Hertzum 2024). Thereby, repair also has a role in revealing unsustainable work conditions.

5.4 Limitations

Three limitations should be remembered in interpreting the results of this study. First, we acknowledge that the results are from one analysis. While it includes two cases, there is more to medication management than medication reconciliation and closed-loop medication management. To validate our results, future studies should span medication-management practices other than those two, cultural contexts other than Norwegian healthcare, and primary methods other than interviews. Second, we specifically recognize that the two practices studied are collaborative in a serial manner. While physicians, pharmacists, and nurses all contribute, they tend to do so at different points and times. This characteristic of medication management influences the repair work involved, especially its collaborative element. Repair should also be studied in relation to practices that entail same-time, same-place collaboration. Third, repair is one of several concepts about keeping things in working order. We discuss the relation between repair work and articulation work but do not provide a comparison between repair and further concepts for getting things back on track when they are disrupted by breakdown. However, we acknowledge that a conceptual analysis of the similarities and dissimilarities between repair and concepts such as infrastructuring and workarounds would be a valuable contribution to the research on computer-supported cooperative work.

6 Conclusion

In spite of the infrastructure in place to avert errors in medication management, the activities of medication reconciliation and closed-loop medication management involve collaborative, continuous, and critical repair work. We have shown that without this repair work, medication management would collapse. While the issues that bring repair about revolve around breakdowns in the order of things, the implications of repair are more varied. We find that (1) continuous repair has the double effect of making medication management both resilient and fragile, (2) some breakdowns recur at a frequency that routinize the repair work, (3) routinized and improvisational repair differ in their emphases, (4) repair work is exported to later stages when the initial repair achieves an insufficient level of repairedness, (5) the repair of complex and fragmented data requires infrastructure

functionality for gaining an overview of the data, (6) the amount of repair work appears to be increasing with the growing number of increasingly complex technologies, (7) the concept of repair contributes to distinguishing analytically among different forms of breakdown, and (8) repair has an important role in revealing stressful and otherwise unsustainable work conditions. Future improvement in the electronic support of medication management should heed the substantial work involved in keeping medication management in working order.

Acknowledgements

This paper combines and thoroughly extends the analyses of two empirical cases that have previously been presented in separate conference papers (Bjørnstad and Ellingsen 2022; Ellingsen et al. 2024). Special thanks are due to the interviewees.

Author Contribution

M.H. and G.E. collaboratively conceived the idea for the study. G.E. and M.H. conducted the empirical study at Narvik Hospital. C.B. and G.E. conducted the empirical study at Kalnes Hospital. M.H. wrote the manuscript text. All authors reviewed and approved the manuscript.

Funding

Open access funding provided by Roskilde University. This study is part of the eMM project, which is funded by the Research Council of Norway (grant no. 314382).

Data Availability

The authors do not have permission to make the interviews and other data from the study available.

Declarations

Conflicts of interest

The authors declare no competing interests.

Ethical Approval

The Data Protection Office at the University Hospital of North Norway approved the study (project no. 0439) and waived the need for written consent. In addition, we got written approval from the research director at Kalnes Hospital.

Consent to Participate

All participants orally consented to take part.

Open Access
This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Agrawal, Abha. 2009. Medication errors: Prevention using information technology systems. *British Journal of Clinical Pharmacology* 67 (6): 681–686. https://doi.org/10.1111/j.1365-2125.2009.03427.x.

Ahmed, Syed I., Steven J. Jackson, and Md R. Rifat. 2015. Learning to fix: Knowledge, collaboration and mobile phone repair in Dhaka, Bangladesh. In *Proceedings of ICTD2015 Conference on Information and Communication Technologies and Development*, 1–10. New York: ACM. https://doi.org/10.1145/2737856.2738018

Andersen, Tariq O. 2013. Medication management in the making: On ethnography-design relations. In *Proceedings of the CSCW2013 Conference on Computer Supported Cooperative Work*, 1103–1112. New York: ACM. https://doi.org/10.1145/2441776.2441901

Bingham, Gordon, Erica Tong, Susan Poole, Paul Ross, and Michael Dooley. 2021. A longitudinal time and motion study quantifying how implementation of an electronic medical record influences hospital nurses' care delivery. *International Journal of Medical Informatics* 153: 104537. https://doi.org/10.1016/j.ijmedinf.2021.104537.

Bjørnstad, Camilla, and Gunnar Ellingsen. 2022. Medication quality and work practice. *Procedia Computer Science* 196: 673–683. https://doi.org/10.1016/j.procs.2021.12.063.

Bovet, Alain, and Ignaz Strebel. 2019. Job done: What repair does to caretakers, tenants and their flats. In *Repair work ethnographies: Revisiting breakdown, relocating materiality*, eds. I. Strebel, A. Bovet, and P. Sormani, 89–125. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8_4

Bowker, Geoffrey C. 1994. *Science on the run: Information management and industrial geophysics at Schlumberger, 1920–1940*. Boston, MA: MIT Press.

Cabitza, Frederico, and Carla Simone. 2013. "Drops hollowing the stone": Workarounds as resources for better task-artifact fit. In *ECSCW 2013: Proceedings of the 13th European Conference on Computer Supported Cooperative Work*, 103–122. Cham: Springer. https://doi.org/10.1007/978-1-4471-5346-7_6

Choo, Janet, Alison Hutchinson, and Tracey Bucknall. 2010. Nurses' role in medication safety. *Journal of Nursing Management* 18 (7): 853–861. https://doi.org/10.1111/j.1365-2834.2010.01164.x.

Corbin, Juliet M., and Anselm L. Strauss. 1993. The articulation of work through interaction. *The Sociological Quarterly* 34 (1): 71–83. https://doi.org/10.1111/j.1533-8525.1993.tb00131.x.

Crang, Mike. 2010. The death of great ships: Photography, politics, and waste in the global imaginary. *Environment and Planning A: Economy and Space* 42 (5): 1084–1102. https://doi.org/10.1068/a42414.

Denis, Jérôme, and David Pontille. 2019. The dance of maintenance and the dynamics of urban assemblages: The daily (re)assemblage of Paris subway signs. In *Repair work ethnographies: Revisiting breakdown, relocating materiality*, eds. I. Strebel, A. Bovet, and P. Sormani, 161–185. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8_6

Ellingsen, Gunnar, Morten Hertzum, Gro-Hilde Severinsen, and Rolf Wynn. 2024. Medication reconciliation as repair work. In *MEDINFO2023 Proceedings*, 104–108. Amsterdam: IOS Press. https://doi.org/10.3233/SHTI230936

Fernandes, Olavo, and Kaveh Shojania. 2012. Medication reconciliation in the hospital: What, why, where, when, who and how? *Healthcare Quarterly* 15 (special issue): 42–49. https://doi.org/10.12927/hcq.2012.22842.

Flanagan, Nina. 2018. Medication reconciliation: A necessary process for patient safety. *Caring for the Ages* 19 (8): 14–15. https://doi.org/10.1016/j.carage.2018.07.012.

Franklin, Bryony D., Kara O'Grady, Parastou Donyai, Ann Jacklin, and Nick Barber. 2007. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: A before-and-after study. *Quality and Safety in Health Care* 16 (4): 279–284. https://doi.org/10.1136/qshc.2006.019497.

Gil, Liliana. 2024. Becoming a repair entrepreneur: An ethnography of skills training in Brazil. *Third World Quarterly* 45 (4): 640–657. https://doi.org/10.1080/01436597.2023.2207006.

Graham, Stephen, and Nigel Thrift. 2007. Out of order: Understanding repair and maintenance. *Theory, Culture & Society* 24 (3): 1–25. https://doi.org/10.1177/0263276407075954.

Hansen, Sine S. 2024. Disconnecting the communicating body: On the human work of articulation, maintenance, and repair in the use of personal tracking devices. In *The digital backlash and the paradoxes of disconnection*, eds. K. Albris, K. Fast, F. Karlsen, A. Kaun, S. Lomborg, and T. Syvertsen, 193–214. Gothenburg: Nordicom, University of Gothemburg. https://doi.org/10.48335/9789188855961-10.

Hanseth, Ole, and Kristin Braa. 2001. Hunting for the treasure at the end of the rainbow: Standardizing corporate IT infrastructure. *Computer Supported Cooperative Work* 10 (3&4): 261–292. https://doi.org/10.1023/A:1012637309336.

Hector, Philip, and Andrea Botero. 2022. Generative repair: Everyday infrastructuring between DIY citizen initiatives and institutional arrangements. *CoDesign* 18 (4): 399–415. https://doi.org/10.1080/15710882.2021.1912778.

Henke, Christopher R. 2000. The mechanics of workplace order: Toward a sociology of repair. *Berkeley Journal of Sociology* 44: 55–81.

Henke, Christopher R. 2019. Negotiating repair: The infrastructural contexts of practice and power. In *Repair work ethnographies: Revisiting breakdown, relocating materiality*, eds. I. Strebel, A. Bovet, and P. Sormani, 255–282. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8_9

Houston, Lara, Steven J. Jackson, Daniela K. Rosner, Syed I. Ahmed, Meg Young, and Laewoo Kang. 2016. Values in repair. In *Proceedings of the CHI2016 Conference on Human Factors in Computing Systems*, 1403–1414. New York: ACM. https://doi.org/10.1145/2858036.2858470

Jackson, Steven J. 2014. Rethinking repair. In *Media technologies: Essays on communication, materiality, and society*, eds. T. Gillespie, P.J. Boczkowski, and K.A. Foot, 221–239. Boston, MA: MIT Press.

Jung, Ju Y., Tom Steinberger, John L. King, and Mark S. Ackerman. 2021. Negotiating repairedness: How artifacts under repair become contingently stabilized. *Proceedings of the ACM on Human-Computer Interaction* 5 (CSCW2): 1–29. https://doi.org/10.1145/3476069.

Klein, Heinz K., and Michael D. Myers. 1999. A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly* 23 (1): 67–93. https://doi.org/10.2307/249410.

Lejeune, Christophe. 2019. Interruptions, lunch talks, and support circles: An ethnography of collective repair in steam locomotive restoration. In *Repair work ethnographies: Revisiting breakdown, relocating materiality*, eds. I. Strebel, A. Bovet, and P. Sormani, 221–251. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8_8

Makary, Martin A., and Michael Daniel. 2016. Medical error - The third leading cause of death in the US. *BMJ (Clinical research ed.)* 353: i2139. https://doi.org/10.1136/bmj.i2139.

Mekonnen, Alemayehu B., Tamrat B. Abebe, Andrew J. McLachlan, and Jo-anne E. Brien. 2016. Impact of electronic medication reconciliation interventions on medication discrepancies at hospital transitions: A systematic review and meta-analysis. *BMC Medical Informatics and Decision Making* 16 (1): 112. https://doi.org/10.1186/s12911-016-0353-9.

Mikalsen, Marius, Babak A. Farshchian, and Yngve Dahl. 2018. Infrastructuring as ambiguous repair: A case study of a surveillance infrastructure project. *Computer Supported Cooperative Work* 27 (2): 177–207. https://doi.org/10.1007/s10606-017-9302-0.

Pevnick, Joshua M., Rita Shane, and Jeffrey L. Schnipper. 2016. The problem with medication reconciliation. *BMJ Quality & Safety* 25 (9): 726–730. https://doi.org/10.1136/bmjqs-2015-004734.

Phillips, David P., and Charlene C. Bredder. 2002. Morbidity and mortality from medical errors: An increasingly serious public health problem. *Annual Review of Public Health* 23:135–150.

Pink, Sarah, Juan F. Salazar, and Melisa Duque. 2019. Everyday mundane repair: Banknotes and the material entanglements of improvisation and innovation. *Tapuya: Latin American Science, Technology and Society* 2 (1): 458–477. https://doi.org/10.1080/25729861.2019.1636619.

Reddy, Madhu C., Paul Dourish, and Wanda Pratt. 2001. Coordinating heterogeneous work: Information and representation in medical care. In *ECSCW2001: Proceedings of the European Conference on Computer Supported Cooperative Work*, 239–258. Dordrecht: Kluwer. https://doi.org/10.1007/0-306-48019-0_13

Rosner, Daniela K., and Morgan Ames. 2014. Designing for repair? Infrastructures and materialities of breakdown. In *Proceedings of the CSCW2014 Conference on Computer Supported Cooperative Work and Social Computing*, 319–331. New York: ACM. https://doi.org/10.1145/2531602.2531692

Sambasivan, Nithya, Shivani Kapania, Hannah Highfill, Diana Akrong, Praveen Paritosh, and Lora M. Aroyo. 2021. "Everyone wants to do the model work, not the data work": Data cascades in high-stakes AI. In *Proceedings of the CHI2021 Conference on Human Factors in Computing Systems*, 1–15. New York: ACM. https://doi.org/10.1145/3411764.3445518

Schmidt, Kjeld, and Liam Bannon. 1992. Taking CSCW seriously - Supporting articulation work. *Computer Supported Cooperative Work* 1 (1&2): 7–40. https://doi.org/10.1007/BF00752449.

Schubert, Cornelius. 2019. Repair work as inquiry and improvisation: The curious case of medical practice. In *Repair work ethnographies: Revisiting breakdown, relocating materiality*, eds. I. Strebel, A. Bovet, and P. Sormani, 31–60. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8_2

Simonsen, Jesper, Helena Karasti, and Morten Hertzum. 2020. Infrastructuring and participatory design: Exploring infrastructural inversion as analytic, empirical and generative. *Computer Supported Cooperative Work* 29 (1&2): 115–151. https://doi.org/10.1007/s10606-019-09365-w.

Stana, Raluca A., and Morten Hertzum. 2024. Technostress in nuclear medicine: A qualitative study of causes, mitigators, and resolution levels. *International Journal of Medical Informatics* 190: 105547. https://doi.org/10.1016/j.ijmedinf.2024.105547.

Star, Susan L., and Karen Ruhleder. 1996. Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research* 7 (1): 111–134. https://doi.org/10.1287/isre.7.1.111.

Strauss, Anselm, Shizuko Fagerhaugh, Barbara Suczek, and Carolyn Wiener. 1985. *Social organization of medical work*. Chicago, IL: University of Chicago Press.

Strebel, Ignaz, Alain Bovet, and Philippe Sormani, eds. 2019. *Repair work ethnographies: Revisiting breakdown, relocating materiality*. Singapore: Springer Nature. https://doi.org/10.1007/978-981-13-2110-8.

Suchman, Lucy A. 2007. *Human-machine reconfigurations: Plans and situated actions*, 2nd ed. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511808418.

Tanweer, Anissa, Brittany Fiore-Gartland, and Cecilia Aragon. 2016. Impediment to insight to innovation: Understanding data assemblages through the breakdown–repair process. *Information, Communication & Society* 19 (6): 736–752. https://doi.org/10.1080/1369118X.2016.1153125.

Torsvik, Torbjørn, Børge Lillebo, and Morten Hertzum. 2018. How do experienced physicians access and evaluate laboratory test results for the chronic patient? A qualitative analysis. *Applied Clinical Informatics*. https://doi.org/10.1055/s-0038-1653967.

Verdezoto, Nervo, Naveen Bagalkot, Syeda Z. Akbar, Swati Sharma, Nicola Mackintosh, Deirdre Harrington, and Paula Griffiths. 2021. The invisible work of maintenance in community health: Challenges and opportunities for digital health to support frontline health workers in Karnataka, South India. *Proceedings of the ACM on Human-Computer Interaction* 5 (CSCW1): 1–31. https://doi.org/10.1145/3449165.

Wagner, Erica L., and Sue Newell. 2006. Repairing ERP: Producing social order to create a working information system. *Journal of Applied Behavioral Science* 42 (1): 40–57. https://doi.org/10.1177/0021886305284290.

Walsham, Geoff. 2006. Doing interpretive research. *European Journal of Information Systems* 15 (3): 320–330. https://doi.org/10.1057/palgrave.ejis.3000589.

Zhang, Zhan, Karen Joy, Richard Harris, and Sun Y. Park. 2022. Characteristics and challenges of clinical documentation in self-organized fast-paced medical work. *Proceedings of the ACM on Human-Computer Interaction* 6 (CSCW2), 386. https://doi.org/10.1145/3555111.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.