Implementing an Intersectoral Telemedicine Network in Rural Areas: Evaluation from the Point of View of Telemedicine Users

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Abstract: Telemedicine (TMed) is becoming popular due to the growing number of elderly and the shortage of healthcare workers. In Germany, TMed is rarely part of rural healthcare, and the research state is limited. To improve healthcare and to research the conditions under which TMed can be used in German rural areas, an intersectoral, TMed network was set up from July 2018 to Oct. 2020 and evaluated with mixed methods, including qualitative interviews and quantitative feedback forms. Seven Use-Cases (UCs) were implemented in the dimensions: (i) home visits ($n = 170$), (ii) patient video consultation ($n = 30$), (iii) intensive care ($n = 15$), (iv) mountain accident ($n = 6$), (v) wound management ($n = 6$), (vi) caregiver video consultation ($n = 3$) and (vii) electronic health record ($n = 10$). Our study indicates that digitally supported general practitioner (GP)-home visits and intensive care are the most frequent UCs. TMed is satisfactory and leads to advantages for rural healthcare. However, vital data transmission and the electronic health record (eHR) were less in demand due to high preparation efforts. Findings from previous studies can be confirmed. Facilitators for TMed who should be considered and further researched are: training on digital literacy including awareness-rising, financing, cross-institutional documentation, and suitable mobile network infrastructure.

1 INTRODUCTION

European Challenges. Increasing multi-morbidity and treatments for chronic diseases in an aging society in Western Europe are putting pressure on health systems. In Germany, one in five people is over 65 years of age (Dudel, 2018, p. 5), and rising life expectancy leads to an increase in the number of elderly requiring treatment in Europe (European Parliament, 2021). There are several challenges Health Service Providers (HSPs) face: (i) disciplines become more specialized, (ii) services get increasingly fragmented, (iii) overall complexity is increasing and (iv) no inefficiencies can be afforded due to the shortage healthcare workers (HCWs) (Valentijn et al., 2013; Hackmann and Moog, 2010; Tsiasioti et al., 2020).

Rural Challenges. Equal opportunities between urban and rural areas and the same access to health services are a priority for many European countries (Weingarten and Steinführer, 2020). Many rural general practitioner (GP) vacancies won't be filled in the future because there often is no succession planning (Kopetsch, 2010; Laschet, 2019). Another challenge is that young people are the backbone of rural development, but due to urbanization, they are missing in rural healthcare jobs, and the role of informal caregiver remains unfilled (Hennig, 2019). Therefore, the rural elderly are increasingly dependent on professional health and care services in rural regions (Bayerisches Landesamt für Statistik, 2019b).

In rural areas, there is a shortage of rural HCWs and conversely a high demand for health services (Hackmann and Moog, 2010; Tsiasioti et al., 2020). In addition, a large portion of work time of HCWs is spent on not direct patient care tasks (e.g., administration or travel). Some German regions are sparsely populated with, e.g., 80 residents per km^2, and travel times for home visits or clinic admissions take longer than in cities (Bayerisches Landesamt für Statistik, 2019a, p. 14). The fact that rural HSPs travel long distances to visits or examinations (e.g., vital parameter checks) is costly, ineffective and reduces the attractiveness of the health profession (Meyer, 2020). In addition, not only obtaining

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timely care is critical, even the time for patient care is reduced as well as medical and paramedical staff are burdened. The patient's situation is similar because mobility is reduced with increasing age and house visits have capacity bottlenecks. Furthermore, they often have to deal with a lack of specialist support in close vicinity, which makes it difficult to get treatment for complex conditions without traveling longer distances (Löffler et al., 2021). Treatment delays can lead to worse health outcomes (Meyer, 2020).

TMed as a Solution. Telemedicine (TMed) is using medical data exchange from distinct locations via electronic communication to improve patient's health and bridge distances (Schwab, 2020). Since COVID-19, protecting vulnerable patients from infections has become more important in rural areas, where the loss of personnel becomes directly noticeable (Knörr et al., 2022). In rural areas, HSPs serve a remarkably vital role in the care of their communities, and TMed can contribute to infection protection. TMed even has the potential to close the gap in healthcare access and alleviate disparities between rural and urban healthcare delivery.

Research Focus. The *main contribution* is to show how TMed in german rural areas can improve health care. Contrary to prior studies, our applied study presents a multisided picture of rural TMed, uncovers barriers, and shows how individual TMed applications fit into a bigger intersectoral network.
The remaining paper is structured as follows: We review the current literature on rural TMed in Section 2, highlighting the existing barriers and research gaps. In Section 3, we present how we established an intersectoral TMed network (Subsection 3.1) and evaluated it (Subsection 3.2). The results are presented in Section 4. The paper ends with a discussion in Section 5, a conclusion, and an outlook in Section 6.

2 RELATED WORK

The scientific community dealt with TMed and telerehabilitation, focusing on mental health, home care, primary care, and emergencies (Butzner and Cuffee, 2021; Speyer et al., 2018). Plenty of research even focused on teleconsultation as a technical application for communication between professionals and patients (Yamano et al., 2022). Due to COVID-19, the publication record has increased significantly (Mbunge et al., 2022; Şahin et al., 2021).

2.1 International Perspective

Regarding international studies, much of the applied science is being carried out in emerging, and developing countries since TMed usually represents the only care option here. For example, in the Himalayan region, patients were provided with TMed (treatment and health education) in their homes and rural care centers because of a rural physician shortage (Amatya et al., 2022; Ganapathy et al., 2019).

Outcomes and Effects. Most high-level TMed evidence focus on clinical outcomes and cost-effectiveness, with findings that TMed is at least as effective as standard care and can reduce costs for patients as well as HSPs (Speyer et al., 2018; Zhang et al., 2022b; Butzner and Cuffee, 2021). The cost-benefit analysis is complex since TMed first requires investments and pay off later (Goharinejad et al., 2021). Eliminating the need for travel, TMed can help reduce the cost of care for patients and HSP (Zhang et al., 2022a). TMed is also convenient, and patients often recommend it to others (Sekhon et al., 2021). Furthermore, TMed advantage people with limited mobility or social isolation (Banbury et al., 2018).

The outcome of TMed is greater than saving time and costs in overall care. TMed offers versatile opportunities for elderly, multimorbid, and mobility-impaired people and can compensate for disparities (Batsis et al., 2019). Teleconsultations can preventively avoid hospital admissions and thus a high burden on patients due to a new environment and starting treatment too late (Batsis et al., 2019). In particular, the connection of medical devices, such as an ECG or wearables, can monitor health status and complement existing care (Yamano et al., 2022).

There are several advantages to TMed in rural areas, including the (i) ability to reach underserved populations (better healthcare access), (ii) the provision of care at a lower cost and (iii) the potential to improve clinical outcomes (Haleem et al., 2021). The most obvious TMed benefit is the reduction of infection risks and increased protection against COVID-19 in fragmented health care (Mbunge et al., 2022). Further, patient satisfaction with TMed is good, and patients accept them (Sekhon et al., 2021; Batsis et al., 2019). HCW also show overall satisfaction, acceptance and see opportunities for better relationships with patients (Odendaal et al., 2020). TMed also transforms the work of HCWs, creating flexibility and better coordination in care so that resource utilization can be improved (Butzner and Cuffee, 2021).

Outcomes depend on applications and clinical picture: In diabetes, an improvement in blood glucose

control and self-management of health can be observed (Zhang et al., 2022a). TMed also has psychological effects, reducing negative emotions and enhancing medication adherence (Ma et al., 2022). TMed also decreases hospital admissions and severe adverse effects (Batsis et al., 2019). Many existing studies are biased and consider only one specific disease (Batsis et al., 2019), although society gets more multimorbid (The American Geriatrics Society, 2012). This raises the question about the transferability of existing studies, shown in Table 1.

Table 1: International evidence on TMed in rural areas.

Findings of Reviews	**Source**
Better or comparable outcomes (TMed & face-to-face)	(Goharinejad et al., 2021; Batsis et al., 2019; Şahin et al., 2021; Speyer et al., 2018)
Decreased direct and indirect costs for patient & health service	(Butzner and Cuffee, 2021; Haleem et al., 2021; Speyer et al., 2018; Zhang et al., 2022b)
Better resource allocation & staff relief	(Butzner and Cuffee, 2021)
Satisfaction and acceptance by patients & healthcare workers	(Sekhon et al., 2021; Butzner and Cuffee, 2021; Mbunge et al., 2022)
Outcomes are limited due to heterogeneity: rural areas need further research	(Butzner and Cuffee, 2021; Speyer et al., 2018; Yamano et al., 2022; Banbury et al., 2018; Batsis et al., 2019; Şahin et al., 2021)

Barriers and Facilitating Factors. The main barriers to implementing TMed in rural areas are: (i) lack of infrastructure, (ii) limited resources and (iii) lack of provider training. To provide remote access to medical care, TMed requires a reliable internet connection in remote areas. While most of the population has access to broadband internet, the picture is switching for mobile applications in rural areas, where connectivity gaps exist (Baake and Mitusch, 2021). Insufficient mobile connectivity makes it difficult to provide or receive care via TMed. In addition, emerging and developing countries struggle with affordable internet connection and electricity isn't always available (Odendaal et al., 2020). However, the reliability of solutions is especially (esp.) important when consulting emergencies (Yamano et al., 2022). In this context, technical support is important. Furthermore, the interoperability of TMed solutions, esp. a unified electronic health record (eHR), will determine the success or failure of TMed (Haleem et al., 2021).

Time must be invested first to find and train the resources needed for TMed deployment. Similarly, the training of health workers is quite important in this context, and the solutions must be user-friendly and integrate with existing systems (Odendaal et al., 2020). Accessibility can be essential because hearing problems or sign language can be a problem for current TMed (Şahin et al., 2021).

The *Chochrane Library* revealed that concerns exist in the form of supervision, threatening one's competence, and fears of being overworked and depersonalized (Odendaal et al., 2020). These should be addressed to promote TMed. Digital literacy is limited in some cases. For successful TMed deployment, user training and guidance were needed (Banbury et al., 2018). Also, concerns exist about the reliability of TMed, and sometimes interventions can't be delivered with TMed at all (Sekhon et al., 2021). Some interventions even require additional people to perform physical exams. Further research on barriers and facilitating factors are needed to accelerate the uptake of TMed (Banbury et al., 2018; Şahin et al., 2021).

2.2 National Perspective

National Achievements. Germany's TMed efforts are focused on providing access to care for rural and under-served populations, enhancing coordination, and lowering costs. One of the notable german TMed efforts is the creation of legal foundations (e.g., e-health law and digital healthcare act) for implementing, billing, and TMed delegation of medical services. Even though the government wants to advance TMed, some regulatory burdens, such as changing professional codes, billing arrangements, and indication for TMed, still need to be changed (Peine et al., 2020). The TMed efforts are slowly translating to countrywide care, although COVID-19 leads to an increased TMed demand (Peine et al., 2020). Much TMed applications are piloted and focused on specific diseases, esp. cardiovascular disease or mental health. Furthermore, most applications include certain regions or professions (Allner et al., 2019).

Further Needs. Various associations, such as the German Society for TMed (DGTELEMED) and national alliances (e.g., Bavarian TMed Alliance), promote TMed. Regional networks or projects exist within funding limits and have specific Use-Cases

(UCs), e.g., stroke care, mental health, and primary care. Partly complex applications such as the diagnosis of dementia via videoconferencing or TMed supported stroke units have been well-tested (Barth et al., 2018; Mathur et al., 2019). In addition, previously applied science on TMed is often unsystematic, and many results aren't published (Allner et al., 2019).

Lack of Transferable Research. Table 2 shows that experience is limited in the field of TMed in Bavaria with promising effects, although further research is required (Black et al., 2011). National studies have shown a broad acceptance of TMed by health professionals and patients, but there is untapped potential in the actual use (Muehlensiepen et al., 2021; Kirchberg et al., 2020; Techniker Krankenkasse, 2022; van den Berg et al., 2009; von Solodkoff et al., 2020). Many health professionals share the assessment that TMed measures improve care and represent a solution strategy for current challenges (Beckers and Stellmacher, 2021, p. 60).

The elaborated international outcomes seem similar, but there isn't enough research to derive a clear conclusion for Germany (Knörr et al., 2022). Most studies have low evidence levels, and the effects are unclear. Some studies attest to a potential positive benefit of TMed in the form of a reduction in the workload of GPs, although the increase in quality of care and safety hasn't yet been conclusively clarified (Black et al., 2011; Grohs and Thiess, 1997). The effects always depend on the application scenario. esp. treating skin diseases and wounds is a time-saving and effective TMed application field (Eber et al., 2019; Jünger et al., 2019). Furthermore, omnipresent economic benefits, such as saving time and money by avoiding unnecessary clinic visits, reducing travel time, and utilizing more GPs working time for direct patient care, are fulfilled by TMed. Nonetheless, many studies can't calculate exact savings (Gensorowsky et al., 2021). Yet, it should be clear by the nature of TMed that elderly with limited mobility benefit from positive effects in their quality of life through telediagnostics (Bohnet-Joschko and Stahl, 2019; Partheymüller et al., 2019).

Explore Barriers Nationally. Nationally, barriers reducing the use of TMed exist mainly structurally (Peine et al., 2020). Barriers are related to financing, technical infrastructure, fear of misdiagnosing, lack of interfaces, and missing resources, e.g., GP shortage (Weißenfeld et al., 2021). The indications for TMed are also limited by the impossibility of examining patients directly physically, i.e., either self-tests or non-medical specialists are needed (von Solodkoff et al., 2020). The digital literacy of HCWs primarily needs improvement, esp. in the legal aspects and data safety of TMed (Kirchberg et al., 2020). Privacy knowledge and ambiguity regarding terminology, digital treatment concepts, and evaluation or improvement of TMed measures are demanding (Köhnen et al., 2019; von Solodkoff et al., 2020).

The barriers for TMed can reduce use and acceptance. The literature cited so far doesn't explicitly examine the barriers nationally, doesn't communicate transparently, and doesn't compare effects between rural and urban TMed. We are unaware of any study examining barriers to TMed in rural areas. Furthermore, international experience can only be transferred to Germany to a limited extent due to the country's special structure and form of government organization (Kidholm et al., 2012). This is exactly why further research in the field is important.

3 METHODOLOGY

From *July 2018 to October 2020*, we implemented an intersectoral TMed network in a German rural region. We focus on UCs that deliver diagnostics and therapy to the patient or HCWs due to audio-visual communications, the transmission of vital data between GPs and non-physician staff, and a commercial eHRs. First, we describe the TMed network and the considered UCs in Subsection 3.1, followed by a description of the evaluation approach with Subsection 3.2.

3.1 Framework, Setup, and Use-Cases

After analyzing the requirements and opportunities, we implemented an intersectoral TMed network in Lower Bavaria consisting of several HSPs: one GP, two regular clinics, one special clinic, two nursing homes, and one intensive care provider with residential care communities. Furthermore, a mountain shelter without para-/medical professionals was added to the network (see UC 4). The HSPs relations are shown in Figure 1.

Applied Technology. Various HSPs were equipped gradually with TMed gear available in 2018. We chose the equipment after market research in which we considered: security, interfaces, usability, and training. Because prior studies showed that common documentation is vital, a commercial eHR *Vitabook*®[1] was used. For audio-visual communication as well as the mobile and stationary transmission of video,

[1] www.vitabook.de, accessed on 2023-02-06

Table 2: Bavarian TMed projects, cf. (Jedamzik, 2022).

Project title	**content**
eNurse[a]	TMed network of specialists and GPs, established itself as an enterprise
SPeed[b]	Cross-sector care record, TMed-network of GPs & geriatric-/ nursing homes
TEMPiS[c]	TMed stroke care with special & regular clinics
Gesundheitsversorgung 4.0[d]	GPs, pharmacy, nursing service & patients communicate via TMed

[a] High Franconia [b] Ingolstadt Region [c] entire Bavaria [d] High Franconia

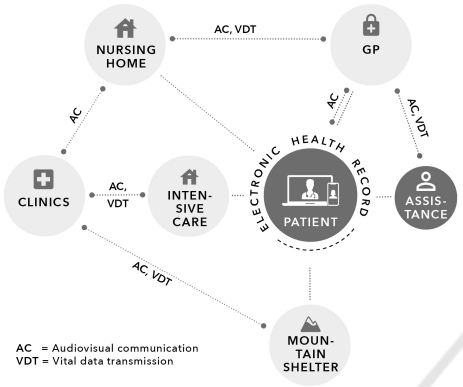

Figure 1: HSPs relationship within the TMed network.

images, and text, *MEYDOC*®[2] was used. For the transmission of vital data, such as electrocardiogram (ECG) data, Heart Rate Variability (HRV)rate, Blood pressure (BP) and oxygen saturation, we used the mobile medical product *DynaVision*[3]

Use-Cases (UCs). With the described equipment, we investigated seven TMed UCs as shown in Table 3.

In UC 1, we investigated TMed support of home visits. Medical assistants could contact the GP audiovisually during home visits, transmit vital data, and carry out certain activities by delegation. The GP also offered video consultations for patients (UC 2) directly to reduce the risk of COVID-19 infections.

In UC 3, we connected an intensive care service with a specialist clinic for respiratory diseases. The TMed coordination and optimization of ventilation parameters between the two HSPs were investigated with online visits scheduled or organized ad hoc.

In UC 4, non-medical staff at the mountain shelter were networked with the hospital to support rescue or first aid in the event of mountain accidents.

During the project, it emerged that digital support for wound management in nursing represents a useful field of application (UC 5). Furthermore, we set up digital consultation hours with the GP and the care facility to discuss critical patients before the weekend.

[2]www.meydoc.de, accessed on 2023-02-06

[3]No longer available; supplier: www.eurovation.de

In all UCs, the eHR should be used as uniform documentation and information basis (UC 7).

3.2 Evaluation Methodology

For evaluating the conditions of rural TMed and to answer the research question on how TMed can improve rural health care, a mixed-method approach was used following *Kuckartz* (Kuckartz, 2014).

Quantitative Approach. Quantitatively the case numbers, reasons for use, UCs as well as satisfaction after each consultation were recorded using analog feedback forms. Corresponding feedback forms were filled out by GP, intensive care, and nursing home staff. The data about the consultations were entered and analyzed with *IBM SPSS*® *Ver. 24*.

Because of limited case numbers (see Table 4), data analysis was only descriptive. The feedback forms and the raw data will be provided as supplementary material to this article.

Qualitative Approach. The qualitative approach was intended to clarify the question of the feasibility and acceptance of TMed applications in practice, as well as to record the challenges (i.e., the barriers) and the subjectively perceived outcomes in care multi-dimensionally. Therefore, seven guided interviews were conducted with non- and paramedical staff (nursing home manager, nurse, medical assistant, wound manager, critical care nurse) and the medical profession (GP and specialist physician) from the TMed network. For this purpose, we used a guideline with five main topics, including: (i) biographical context (ii) understanding and acceptance of TMed (iii) coordination and integration (iv) facilitating and inhibiting factors (v) outcomes relevant to care

The interviews were transcribed and analyzed using qualitative content analysis according to *Mayring* (Mayring, 2010). *MAXQDA Vers. 20* was used to support the classification system, consisting of six categories. The classification system is provided as supplementary material to this article.

Table 3: Investigated UCs with involved HSPs and periods.

No.	Use Cases	Providers	Duration
1	Home visits	GP	11.2018 - 10.2020
2	Video consultation for patients	GP	05.2020 - 10.2020
3	Intensive care	care service, specialist clinic	03.2020 - 10.2020
4	Mountain accident	regular hospital, mountain shelter	08.2019 - 11.2019
5	Wound management	nursing home, regular hospital	07.2020 - 10.2020
6	Digital consultation for care	nursing home, GP	09.2019 - 11.2019
7	eHR	GP	02.2019 - 10.2020

4 RESULTS

The presentation of results follows the UCs and ends structurally with contents of the qualitative analysis on success factors and barriers of TMed.

4.1 Case Numbers and Applications

During the survey period, the audio-visual communication application was mainly used by GPs (170 cases) and intensive care units (15 cases). Further relevant case numbers resulted from COVID-19 in video consultation hours for patients (30 cases). Table 4 gives an overview about the investigated UCs.

Table 4: UC with case number.s

No.	Use Case	n
1	Home Visits	170
2	Video Consultation for Patients	30
3	Intensive Care	15
4	Mountain Accident*	6
5	Wound Management	6
6	Digital Consultation Hour for Care*	3
7	Electronic Health Record	10
$\sum$	TMed applications, connections	240

* only test runs, no real emergencies and live environment

Home Visits (*GP* $\Leftrightarrow$ *Medical Assistance*). The possibility for medical assistants to contact the GP audio-visually during home visits was the most common UC ($n = 170$). A total of 1.147 home visits were carried out from Sept. 2018 to Oct. 2020. In 170 cases (14.8 % of all home visits), the medical assistant needed to contact the GP via TMed. Of these 170 cases, communication wasn't possible in 44 cases (25.9 %). The results on (un)successful and not required audio-visual communication between medical assistants and GP during home visits in the studied period are presented in Table 5.

Table 5: Audio-visual communication between medical assistance and GP during a total of 1.147 home visits.

Connection	to all home-visits n	%	only to tele-visits n	%
successful	126	11.0	126	74.1
not successful	44	3.8	44	25.9
not required	978	85.2	-	-

According to the feedback form, the reason for the failed connections of 25.9 % ($n = 44$) is a lack of mobile network coverage. On a query of satisfaction, a sum of $N = 345$ responses was made, of which were $n = 273$ (79.1 %) positive and $n = 72$ (20.9 %) negative. Overall the TMed users are pleased. With the quantitative negative answers, 67 times (92.1 %) the network connection, e.g., the transmission speed, was criticized. Problems with the sound quality (3.2 %) and picture quality (2.0 %) were marginal. The qualitative interviews confirm overall satisfaction and network connection as a barrier 4.2.

Analyzing the successful connections shows that clarification of wound care, with 38.3 % ($n = 64$), is the most common reason for using audiovisual communication, followed by medication management, with 26.4 % ($n = 44$) and unforeseen symptoms in the case of unexpected side effects or a deterioration in health with 4.6 % ($n = 36$). Even in 9.0 % ($n = 15$), patients requested TMed actively an audio-visual contact with the doctor. In 4.8 % ($n = 8$) of the cases, audio-visual communication was used to clarify queries regarding documents from other service providers, such as prescriptions or discharge letters from the hospital.

Video Consultation (*GP* $\Leftrightarrow$ *Patients*). During the COVID-19 pandemic, the GP established a video consultation service for patients. 30 patients used this offer at least once. During the interviews, the GP stated that video consultation is an advantageous offer, although older patients need guidance and a period of acclimatization. Another interviewee, the Nursing

Home Manager (NH-Manager) (para. 13), who uses video consultation privately to discuss laboratory results, emphasizes the savings in time for working people and the protection against viruses: "TMed allows me [...] to discuss my medical needs with a doctor at a controlled time. [...] For me, waiting times in the doctor's office are wasted time and harbor risks of infection." Furthermore, indications of health benefits are given by the same interviewee, the NH-Manager (para. 13): "I would also go to the doctor more because of the elimination of waiting time and do less self-therapy."[4]

Intensive Care (*Nursing Service* ⇔ *Specialist Clinic*). Audiovisual visits ($n = 15$) between the intensive care service and the specialist clinic were used to coordinate ventilation parameters and discuss saturation drops, blood gas analysis, secretion management, and patient mobilization with experts. For organizing the audiovisual visits, pre-appointment was revealed practicably. The visits were conducted in the shared intensive care flats ($n = 11$) and also in the mobile nursing service ($n = 4$). The case numbers in this UC from March 2020 to October 2020 are outlined in Table 6.

Table 6: Use and successful/not-successful application of TMed for audio-visual communication in critical care, depending on Care Flats ($N = 51$) and Home Visits ($N = 24$).

	Care Flats		Home Visits	
Connection	n	%	n	%
successful	11	21.6	4	16.7
not successful	0	0.0	1	4.2
not required	40	78.4	19	79.2

The interviews with the intensive care specialist indicate high satisfaction with the transmission and image quality over the entire application period. The feedback forms and the interviews HCWs mentioned that using an electronic stethoscope would be useful.

Mountain Accident (*Mountain Shelter* ⇔ *Clinic*). During our study, no emergencies or accidents occurred during the test period, so there was no need for actual operation. Therefore only test runs ($n = 4$) with the audio-visual communication could be performed, but they were successful with positive feedback. Non-medical staff from the mountain shelter expressed that user-friendliness was given.

No technical problems regarding connection establishment and transmission quality occurred, as only General Packet Radio Service (GPRS) reception of the vital data transmission with *DynaVision* was required. In the parallel running video communication, there were occasional dropouts because *MEYDOC*® required higher data rates, and network coverage was limited to our mountain shelter.

For the medical staff of the regular clinic, our test runs were an additional burden and a disruptive factor in the daily clinic routine. Although the test runs with the mountain shelter were assessed as useful in principle, the value added for the clinic wasn't seen. In the interview, the GP stated that he saw the advantage but that this special UC would need to be implemented in larger concepts with mountain rescue and the availability of much TMed-supported rescue points.

Wound Management (*Nursing Home* ⇔ *Clinic*). We connected the nursing home to a regular clinic's wound specialist (special nurse education) and carried out digital wound management ($n = 6$). Interviewing the NH-Manager shows positive perceptions regarding wound management: The networking with the clinical wound manager showed above all that simple audio-visual applications, without special cameras, with commercially available tablets, can lead to an adequate assessment of the wound and thus support the care. Interviewing the nurse showed a satisfactory perception of nursing staff and home residents. From the nursing staff's perspective, the ward rounds with a clinical wound manager enrich their work and contribute to empowerment. Since, due to legal conditions and a contract with a special wound care firm, it was impossible to rely exclusively on wound visits with the clinic, an analog on-site wound assessment was carried out in parallel. The video visits and the analog counterpart are comparable in outcomes, i.e., they lead to identical care proposals.

Digital Consultation Hour for Care (*Nursing Home* ⇔ *GP*). In this UC, only successful tests ($n = 3$) in audio-visual communication for digital consultations with the GP to avoid hospital admissions at weekends were carried out. The digital consultations weren't extended to further live operations ($n = 0$) because of "the good weekday doctor presence in the nursing home" and "unpredictability of emergencies, e.g., falls", as said by the NH-Manager. The GP interview even showed that it makes more sense to implement a TMed network with the on-call medical service to clarify emergencies that occur on weekends and avoid unnecessary travel.

Electronic Health Record (GP). A limited number of patients ($n = 10$) that used eHR at least once and the interview with the GP show that there was less

[4] All interview statements were translated from German

eHR acceptance during the project period. However, GPs and research associates created promotional flyers and educated through citizen events. Only ten patients actively used the eHR. The GP states in interviews that benefits of the eHR weren't always seen, and HSPs, which actively use the eHR, were just a few. High-aged patients aren't ever already equipped with mobile devices or weren't digitally experienced enough to use the eHR, which limits accessibility.

4.2 Qualitative Assessment

TMed-Perceptions. The interviews reveal that the perception of TMed is largely positive among the surveyed paramedical and medical staff (3.2). On the HSP side, there were high expectations, and TMed was seen as a chance to transfer expertise, save time, and utilize resources (wound manager, para. 6; medical assistant, para. 4). The use of TMed "is fun" (critical care nurse (CC-Nurse), para. 16), "should be used as often as possible" (CC-Nurse, para. 38), and "enriches skills on many levels" (nurse, para. 28).

But at some points, the interviews reveal fears about liability, the anxiety of extra work for non-physician staff, and fear of another physician's status and estrangement in patient relations (IP 5, para. 34). The GP (para. 35) even remarked: "The fear of making wrong decisions under time pressure is omnipresent. After all, even if TMed brings a lot of relief, I am unsure if TMed has the same quality instead of being on-site." TMed was new for the HSPs, and initially, there were some uncertainties.

Even though patients weren't interviewed, the HCW implied the satisfaction of patients. Similarly, patients explicitly desired audio-visual contact with the GP. The positive patient acceptance is evidenced by an interview statement: "Patients have perceived TMed positively and have been pleased with the new opportunities. The uncomplicated way of consulting experts via TMed was appreciated. [...] An ambulance ride and a visit to the hospital are, after all, not pretty" (wound manager, para. 10). The positive perception of TMed also seems to have increased further during COVID-19 as a catalyst due to the in society more widespread use of digital applications (specialist physician, para. 15) and "digitalization is now more on the agenda" (specialist physician, para. 28). The interviews even show that TMed is changing the paramedical profession and empowering them due to the possibility of delegating medical treatment to non-physicians (wound manager, para. 35).

Outcomes. TMed has multiple outcomes, as evidenced by several interviews. It can be noted that the use of TMed reduces the fear of contact with technology in general (nurse, para. 8). The introduction of TMed has also eliminated General Data Protection Regulation (GDPR) non-compliant solutions such as using private devices with private messaging clients for official purposes like the exchange of wound pictures (NH-Manager, para. 2).

TMed even eliminates waiting and travel times for vulnerable patients, which improves equality of opportunity between healthier and multimorbid patients (NH-Manager, para. 31). According to the GP (para. 30), efficiencies increase because travel times are reduced, and physician work time can be better used for patients through supportive delegation. TMed complements current care and can alleviate some challenges in rural healthcare. TMed allows physicians to "reduce physician work time per patient and helps the personal shortage in rural areas" (wound manager, para. 35). But it is also a relief on the side of the paramedical staff. In the interview with the medical assistant (para. 4), it emerged that queries are clarified more quickly through TMed, thus speeding up the treatment process and making paramedical staff feel more confident or secure.

Intensive care (para. 31) also states that safety for patients and caregivers increases because problems are discussed early, and there is a professional, uncomplicated possibility of contacting expertise through TMed. Early preventive interventions, which are possible through TMed, can improve healthiness: "The patient is fitter, more stable and can also accept therapy recommendations. I can prevent worsenings and therapists can work with more resources" (CC-Nurse, para. 16).

Challenges and Barriers. Despite positive attributions, some barriers, like the mobile network during home visits, resulted in, as noted by GP (para. 18), "lost potential." Participants wanted to use the applications as often as possible. Still frustratingly, potential use was often seen for the applications, but the technology couldn't be used due to cellular coverage. "As an employee, I assume that just works" (medical assistant, para. 17). The TMed-ECG showed a preparation effort due to the adhesive electrodes and, if necessary, shaving of the corresponding areas, which wasn't appropriate if the connection failed. The TMed-ECG was also unwieldy, as shown by the following testimonial: "Since we have so much medical equipment to carry, the ECG is another suitcase that has to be lugged" (medical assistance, para. 28).

Furthermore, structural difficulties are apparent, as expressed in the interview of the NH-Manager and the GP. The following quote from the NH-Manager

(para. 46) sums it up well: "The individual sectors are rather brothers-in-law. Only with a few, I like to go drinking, and with some others, I'm happy if I only see them at Christmas, and then I'm allowed to leave after two hours." The relationship and design of the cooperation are challenging because each HSP works on TMed with its intentions, different revenues, diverse interests, and different efforts. This, in some cases, leads to accusations between HSPs. Furthermore, intersectoral collaboration and process responsibility are challenges. Building relationships takes time because "everyone is cooking their soup and at the beginning HSPs aren't networked" (CC-Nurse, para. 4). Also, not every HSP of the TMed-network was able to prescribe. "Ultimately, it is the family doctor who prescribes" (NH-Manager, para. 25).

Digital prescriptions can't yet be mapped, and many things, such as wound rounds, still have to be done analogically for legal reasons. The interviewees (GP, para. 43 and the special nurse from the clinic, para. 18) also complain about the lack of financial incentives for TMed and poor billing modalities. In addition, the GP and the special nurse from the clinic argue that TMed applications are often "just too expensive" (wound manager, para. 57) and that this is "exploited economically, putting small HSPs at a disadvantage" (GP, para. 44).

Facilitators. The early integration of all rural HSPs promotes TMed since treatments can be coordinated better. TMed deployment is an intersectoral process where it is important to recognize the motivators of each HSP (GP, para. 46). TMed requires certain rules, guidelines, statutes, and adequate privacy and security (CC-Nurse, Abs. 18). Furthermore, it's beneficial if all HSP are "working on the same system with the same things", i.e., they have common information and documentation base like an eHR (GP, para. 46). In this context, "interfaces are desired" (wound manager, para. 16). TMed solutions must be interoperable, i.e., that TMed can be linked to HSP-software.

The need for TMed and digitalization training is evident: "[As employee] there is uncertainty in handling that you have to be guided first." (NH-Manager, para. 8) A high level of digital competence and awareness is helpful, but, as stated by all interviewees, many HSPs are less digitally aware. It is important to sensitize all stakeholders for TMed and take away their fears because if this doesn't happen, then "the TMed won't be used" (nurse, para. 21). Sometimes it also requires, as mentioned by the NH-Manager (para. 30), a good interpersonal understanding, emotional intelligence, and investment in relationships (with employees, partners, and patients). Also, "a period of acclimatization is necessary for everyone, including the patients" (NH-Manager, para. 31).

Likewise, it is important to make TMed as handy and user-friendly as possible. "There are definitely older people who have little experience with digital technology and are afraid to use it" (nurse, para. 35). The interview with the GP and medical assistant stated that TMed should be just easy to use, also the effort required to use the ECG, for example, must be reduced to a minimum TMed acceptance is reduced when problems quickly lead to frustration in the stressful daily care routine (CC-Nurse, para. 38). This was demonstrated by the disconnection of mobile applications in rural areas. Therefore, technology must always work, and regular funding is beneficial for spreading TMed (wound manager, para. 16).

5 DISCUSSION

Subsection 5.1 discussed the methodology and Subsection 5.2 compares the findings with related work.

5.1 Method Discussion

We generated a variety of TMed-UCs with technology that was state of the art (in 2018) when TMed wasn't widespread. The TMed-infrastructure, regulations, and billing were just being introduced (Odendaal et al., 2020; Baake and Mitusch, 2021), so during the project (2018 – 2020), it wasn't possible to compensate the HSP for their TMed-connections. The UCs were carried out in rural Lower Bavaria. This region was chosen due to the challenging HSP situation with a high average age and low population density. (Bayerisches Landesamt für Statistik, 2019b).

Furthermore, the number of cases is restricted in each UC ($N = 240$ applications) because of limited HSPs in rural areas. This doesn't allow multivariate analysis. Another shortcoming is that no telemetry data could be analyzed. To reduce limitations, a mixed-method approach, consisting of quantitative surveys and qualitative interviews, was used according to (Kuckartz, 2014). It allowed exploring the subjective perception of TMed users.

5.2 Results Discussion

Our study draws advantages from testing various UCs with diverse HSPs rather than focusing on a specific clinical picture, as is often the case in national studies (Allner et al., 2019; Barth et al., 2018). Overall we present a multisided picture about TMed in a rural german region, limiting our results generalization.

Table 7: Requirements for rural TMed.

Governance	**Technical**	**HSP-setting**
Legal TMed-framework	Network coverage	Training & Sensitization
Coordination centers	Interoperability	Wide implementation
Intersectoral incentives	Usability & practicability	numerous HSPs-variety
Further applied research	Frustration- & fault-tolerance	Process adaption(s)

In the project, audiovisual communication was used extensively in the GPs and intensive care. In the GP, digital support took place in 14.8% ($n = 170$) of all 1.147 home visits. In our study, 20% ($n = 15$) furthermore of all 75 intensive care treatments TMed were successfully supported by digital tuning ventilation parameters. This field completes the current research, as no corresponding studies exist in rural areas with TMed-intensive care. The numbers would be higher if there weren't connection losses and more project HSPs.

GP and intensive care rated TMed qualitatively as valuable for rural areas. This HSPs may be overrepresented and at bias risk. Other applications, such as vital data transmission and the eHR, were used less (Table 4). The used TMed-vital data transmission needs preparation time (i.e., positioning the electrodes), which doesn't seem practical enough. In addition, the commercial eHR wasn't used much despite a lot of promotion and education. The interviews show indications that the benefits aren't seen and that, at the time of the project, only a few HSPs could use the eHR.

Some of our results are shown in previous studies, like the importance of interference-free applications and infrastructure, esp. mobile networks, as a substantial barrier in rural Areas (Peine et al., 2020; Odendaal et al., 2020). Usability, interoperability, reliable TMed, and training of HCWs for TMed are confirmed as important for TMed-deployment (Yamano et al., 2022; Haleem et al., 2021; Şahin et al., 2021). Some construction sites still exist, such as regulation and incentivizing funding of TMed, confirmed by our study (von Solodkoff et al., 2020). In Complementing the *Cochrane* review (Odendaal et al., 2020), which argues that fears need to be reduced, our study results go beyond this and call for awareness raising and general training in digitization among HCWs and the population at large. It should be considered that the socio-cultural environment can play a role in the TMed-deployment.

The perception of TMeds in our study was positive in the sense of a high acceptance observed in related work (Muehlensiepen et al., 2021; Kirchberg et al., 2020). TMed-benefits can be transferred to rural areas (Hackmann and Moog, 2010). The avoidance of travel time, the reduction of burden on the elderly, and the immediate adjustment of care by TMed are appreciated by HCWs and patients. GPs work time can be better utilized due to reducing traveling. These benefits and increased quality of life are supported by national studies (Black et al., 2011; Knörr et al., 2022; Beckers and Stellmacher, 2021). Promoting further research about TMed in rural areas is necessary. The study populations are mostly restricted.

6 CONCLUSION

This paper outlines the multidimensional benefits of TMed in rural german healthcare. It shows the potential of multisided TMed applications due to an intersectoral TMed network with several HSPs. Due to a mixed-method approach, we evaluated the barriers, facilitators, and perspectives of TMed users.

Summary. Audio-visual communication was heavily used in the GP ($n = 203$). Vital-data transmission was used less for the mountain accident ($n = 6$) and also small in GP ($n = 11$), because of the needed preparation effort. The eHR was used only in a few cases ($n = 10$) as insufficient patients signed up. Although the cases were limited in total ($N = 240$), qualitatively, we highlight that professional users are open to TMed and satisfied with it. The empowerment of the paramedical staff is increased, esp. with audiovisual communication, and they feel more confident. The elimination of travel time led to relief for GPs and their staff and ease to the outpatient and inpatient nursing services. TMed led to efficiency, as time-consuming telephone arrangements or mailings were avoided. In addition, delegation and TMed guidance of medical tasks gave paramedical staff new competencies, which were perceived as enriching. Ambiguities could also be clarified more quickly, creating security. TMed not only avoids unnecessary travel, TMed also reduces the patient's burden.

Recommendations. TMed is feasible and helps to meet rural healthcare needs, as indicated by our study. TMed has benefits in rural areas, particularly in terms of time-saving for GP and intensive care. However, some barriers must be overcome for wider TMed im-

plementation, such as better mobile network coverage in remote areas and financial incentives to collaborate intersectoral (Table 7). TMed must be mostly fail-safe. Furthermore, someone should always be available to act as a coordinating point and take care. Coordination centers should be established, monetary incentives for intersectoral cooperation and TMed should be given, and a wide range of HSP should be involved. Other considerations include coordination and adaptation of the treatment processes among HSPs and digitalization training for TMed users.

Future research should focus on improving the usability of TMed, exploring TMed barriers, and integrating new technologies like Artificial intelligence (AI) and augmented reality. More studies should also conduct knowledge about rural TMed and use bigger study populations and comparison groups.

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