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Bringing diagnostic home: models, challenges and enablers of home-based examinations imaging/graph services – a scoping review

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ABSTRACT

Background Mobile diagnostic imaging services provided at home increase accessibility and convenience, particularly for older adults, people with disabilities and other vulnerable groups. These services can reduce the need for patient travel and support the routine monitoring of chronic conditions. However, current guidelines often overlook user acceptance and environmental considerations within the home setting.

Objectives To map studies that identify the models, barriers and facilitators for performing home-based diagnostic imaging/graph according to end users.

Design A scoping review was conducted following the methodological framework of the Joanna Briggs Institute and reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews checklist.

Eligibility criteria Studies that addressed mobile or portable diagnostic imaging or graph examinations conducted in the home for individuals of any age or health status were included. Studies were eligible if they reported on barriers, facilitators or user experiences. Studies that focused on wearable technologies were excluded.

Sources of evidence The search strategy was developed using terms related to home-based diagnostic imaging/graph, portability, home setting and user perceptions. Searches were conducted in PubMed, Web of Science, Scopus, Embase, The ACM Guide to Computing Literature and LILACS, without restrictions on publication date or language. Additional grey literature was identified through Google Scholar.

Data extraction and synthesis Two reviewers independently extracted data using a standardised form that captured study characteristics, types of procedures, target populations and reported barriers and facilitators. Quantitative data were summarised using absolute and relative frequencies. Qualitative findings were synthesised through basic content analysis to identify and categorise recurring themes.

Charting methods Data were charted in tables to organise and visually map study contexts, methodological features and thematic patterns related to implementation and user experience.

Results Twenty-six studies published between 1998 and 2023 across 15 countries were included. The diagnostic examinations included mostly polysomnography, X-ray imaging and ultrasonography. Seven categories of barriers were identified, such as physical discomfort, equipment-related challenges and procedural limitations. Seven facilitators were also reported, including perceived comfort, patient satisfaction and equipment usability.

Conclusions This review identifies key factors affecting the delivery and user experience of mobile diagnostic imaging at home, including logistical, technical and environmental aspects. It reveals gaps in the literature and provides a basis for future research to inform more inclusive and effective public health policies and service design.

Trial registration number Open Science Framework (DOI 10.17605/OSF.IO/7UV5D).

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A comprehensive search strategy was applied across six major databases and grey literature sources.
⇒ The review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews guidelines to ensure methodological rigour and transparency.
⇒ A broad inclusion criterion was used to capture studies on various types of home-based diagnostic imaging/graph.
⇒ Potential clinical nuances of each imaging modality were not explored in depth.
⇒ Quality appraisal of included studies was not conducted, as is typical in scoping reviews.

INTRODUCTION

Home-based diagnostic (HBD) imaging/graph services have become more common owing to their convenience and accessibility, providing greater comfort to patients and reducing the need for travel. This is especially beneficial for people with reduced mobility or those living in remote areas. These HBD services allow regular monitoring of patients with chronic conditions,

offering fast access to results and enabling early detection of complications, as well as timely treatment adjustments.[1]

Diagnostic imaging enables healthcare providers to look inside the body to identify signs of possible health conditions. Depending on the patient's symptoms and the area of concern, different methods, such as X-ray imaging and ultrasonography, can be used to visualise internal structures and functions.[2] In addition to traditional diagnostic imaging methods, other types of examinations, such as electrocardiography (ECG) and electroencephalography (EEG), although not classified as conventional imaging techniques, also generate visual outputs in the form of graphs or maps.[3]

In recent years, the availability of HBD imaging/graph services has expanded, enabling certain examinations to be performed in the comfort of the patient's home. These HBD services are useful for a wide range of population profiles, including older people, individuals with mobility limitations, children and young adults with diverse physical or intellectual needs. This diversity requires careful consideration of each profile's specific needs to ensure accessibility, comfort and quality when offering HBD imaging/graph services.[4–6] Therefore, governments need to prepare health diagnostic services to serve not only people without limitations who prefer the comfort of home but also those with comorbidities that hinder access to diagnostic centres, as well as socioeconomically vulnerable populations who may face challenges in reaching these facilities.[7]

Available diagnostic imaging examinations vary, and currently, many can be performed at home. Portable equipment such as X-ray systems, ultrasound devices, Doppler, MRI devices, electrocardiogram (ECG) and electroencephalogram (EEG) monitors can be transported by vehicle (adapted vehicles and/or ambulances).[8–12] According to the literature, these services can diagnose various health conditions with the same effectiveness as their non-portable counterparts.[4 13–16]

Performing imaging diagnostics at home offers several benefits for patients. Belo *et al*[17] analysed data from a company that provides home X-ray services and, when comparing it to taking patients to hospitals for these examinations, found a significant cost reduction as well as a decreased need for hospital referrals. Additionally, Lorenzi *et al*[18] reported high patient satisfaction with HBD imaging/graph services, considering various aspects of the care provided. Furthermore, according to Dollard *et al*,[19] patients prefer doing X-ray imaging at home for several reasons, such as the comfort of being in their own home and being surrounded by familiar people, as observed also by Jensen *et al*.[20]

Understanding the scientific literature on these services, as well as their adaptation to user needs, and considering the facilitators and barriers related to providing these services, can help provide essential information to health systems. This information may aid in establishing design guidelines and protocols in the development of equipment and services for HBD imaging/graph, also benefiting industry stakeholders and public health.

Existing guidelines for conducting HBD imaging/graph examinations are mainly focused on ensuring the quality of portable examinations in hospital environments, rather than understanding end user acceptance, including both medical professionals and patients, or on designing a service that considers barriers and facilitators to better serve users at home.[21] Therefore, a literature review to identify, globally, all factors that may describe how HBD imaging/graph examinations are conducted could benefit the field and highlight existing gaps. For this purpose, this scoping review of the literature was conducted, as this methodology can map the breadth of existing evidence on a specific topic.[22]

A search in the Medline, Scopus and Cochrane Library was conducted to assess the originality of this review, identifying three similar reviews.[23–25] However, these reviews differ from the present research in several aspects, including methodological ones, as they are all systematic reviews and focused exclusively on the specific use of a single type of equipment, such as X-ray or ECG. Furthermore, these reviews examined mobile health technologies or specific diagnostic devices, but none specifically focused on the provision of different types of diagnostic procedures with visual or graphical outputs conducted in the home setting, nor did they map the barriers and facilitators involved in their implementation. This scoping review represents the first comprehensive mapping of all types of HBD imaging/graph services, examining both the provision of these services and the barriers and facilitators encountered by end users. Thus, this review aimed to map studies that identify the models, barriers and facilitators for performing HBD imaging/graph according to end users.

METHODS

This scoping review of the literature was conducted according to the recommendations of the Joanna Briggs Institute (JBI) Review Manual[25] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) extension for Scoping Reviews.[26] The protocol for this scoping review was registered in the Open Science Framework (OSF) (DOI 10.17605/OSF.IO/7UV5D).

The research questions were developed based on the population, concept and context strategy, as follows:

(RQ1) What types of home-based diagnostic imaging/graph services have been reported in the literature?

(RQ2) How are home-based diagnostic imaging/graph services conducted?

(RQ3) What are the barriers and facilitators for performing home-based diagnostic imaging/graph according to end users?

(RQ4) Do the barriers and facilitators differ depending on the type of home-based diagnostic imaging/graph conducted?

Eligibility, inclusion and exclusion criteria

The eligibility criterion for studies was that a HBD imaging/graph diagnostic was performed. This review included studies that conducted HBD imaging/graph diagnostic on individuals of all ages and health conditions. There was no age restriction on participants, and the review analysed the barriers and facilitators related to HBD imaging/graph diagnostic services identified by patients, their caregivers or the professionals/stakeholders responsible for the service. Studies need to report on end user experience with HBD imaging/graph services, such as preferences, barriers and facilitators.

The review included studies with data on any type of imaging diagnostic services, such as X-ray imaging, tomography, MRI, angiography, scintigraphy, bone densitometry, mammography or Doppler, as well as diagnostic generating images (eg, graphs) such as ECGs, electrocardiograms, EEGs, cardiotocographs, electroneuromyographs and Holter monitoring. Services could be conducted in any type of dwelling where the study participant resides, such as a house, apartment, nursing homes or long-term care home for older people. Studies were included if they had performed a health monitoring or diagnostic HBD imaging/graph service at home. Only HBD imaging/graph services provided by portable or mobile devices were included. Wearable devices, such as smartwatches, were excluded.

No restrictions were applied on the publication date or language of studies to identify all relevant studies on the topic, broadening the search to include various studies. Studies could be published or unpublished and could have different study designs, including quantitative, qualitative and mixed methods.

The review excluded articles for which full-text copies could not be obtained (after attempts to acquire the text from the database, university library or by contacting authors), technical reports, policy documents, literature reviews and abstracts from academic conferences (due to insufficient study detail, underdeveloped methods and limited results).

Search strategy

A search was conducted in PubMed, Web of Science and Google Scholar to identify descriptors and terms related to this review's topic. Based on this search, the following descriptors were defined: imaging diagnosis, portable, domicile and perspectives, along with their related terms. These descriptors and related terms were incorporated into the search strategies, which were investigated in titles, abstracts and keywords. The search strategy was developed and checked by scoping review experts, and it was adapted to the standards and characteristics of each database, with the addition of Medical Subject Headings (MeSH) terms and Boolean operators as needed. The search conducted in all databases is available in online supplemental material 1. Below is the search strategy for the PubMed database:

("imaging diagnosis"[Title/Abstract] OR "imaging diagnose"[Title/Abstract] OR "image diagnostic"[Title/Abstract] OR "image diagnostics"[Title/Abstract] OR "imaging diagnostics"[Title/Abstract] OR "imaging diagnostic"[Title/Abstract] OR "image based diagnostics"[Title/Abstract] OR "image based diagnostic"[Title/Abstract] OR "imaging based diagnosis"[Title/Abstract] OR "imaging based diagnose"[Title/Abstract] OR "dicom"[Title/Abstract] OR "diagnostic imaging"[Title/Abstract] OR "diagnostic imaging"[MeSH Terms] OR "diagnostic images"[Title/Abstract] OR "diagnostic image"[Title/Abstract] OR ultrasound[Title/Abstract] OR ultrasonography[Title/Abstract] OR ultrasonography[MeSH Terms] OR echocardiogram[Title/Abstract] OR echocardiography[Title/Abstract] OR echocardiography[MeSH Terms] OR xray[Title/Abstract] OR x-ray[MeSH Terms] OR tomography[Title/Abstract] OR tomography[MeSH Terms) OR resonance[Title/Abstract] OR "magnetic resonance imaging"[Title/Abstract] OR "magnetic resonance imaging"[MeSH Terms] OR angiography[Title/Abstract] OR angiography[MeSH Terms] OR scintigraphy[Title/Abstract] OR "bone densitometry"[Title/Abstract] OR mammography[Title/Abstract] OR mammography[MeSH Terms] OR radiology[Title/Abstract] OR radiology[MeSH Terms] OR radiography[Title/Abstract] OR radiography[MeSH Terms] OR radiographs[Title/Abstract] OR doppler[Title/Abstract] OR doppler[MeSH Terms] OR ecg[Title/Abstract] OR eeg[Title/Abstract] OR electrocardiogram[Title/Abstract] OR electroencephalogram[Title/Abstract] OR electroencephalography[Title/Abstract] OR electroencephalography[MeSH Terms] OR cardiotocography[Title/Abstract] OR electroneuromyography[Title/Abstract] OR holter[Title/Abstract]) AND (portable[Title/Abstract] OR mobile[Title/Abstract]) AND (domicile[Title/Abstract] OR residence[Title/Abstract] OR house[Title/Abstract] OR home[Title/Abstract] OR "home care"[Title/Abstract] OR "nursing homes"[Title/Abstract] OR "nursing homes"[MeSH Terms] OR "long-term care"[Title/Abstract] OR "long-term care"[MeSH Terms]) AND (perspective*[Title/Abstract] OR factor*[Title/Abstract] OR preference*[Title/Abstract] OR characteristic*[Title/Abstract] OR experience*[Title/Abstract] OR determinant*[Title/Abstract] OR attribute*[Title/Abstract] OR perception*[Title/Abstract] OR perception[MeSH Terms] OR barrier*[Title/Abstract] OR facilitator*[Title/Abstract])

The investigated databases were PubMed (NIH), Web of Science (Clarivate Analytics), Scopus (Elsevier), Embase (Elsevier), The ACM Guide to Computing Literature (ACM) and Lilacs (BVS), in accordance with the established search strategy. All records generated by the search were transcribed using Excel (Microsoft 365),

with article titles written in the same language to remove duplicates. An additional search in Google Scholar was conducted as an extra strategy to include grey literature studies (unpublished, such as dissertations, theses and course completion papers), where the first 300 studies were reviewed according to Google's relevance algorithm. The databases were searched from September 2023 to February 2024.

Study selection

An initial literature search was conducted in the chosen online databases (PubMed, Web of Science, Scopus, Embase, The ACM Guide to Computing Literature and Lilacs) following the established search strategy. All records generated by the search were transcribed into Excel (Microsoft 365), with article titles written in the same language to facilitate the removal of duplicates.

A pilot test, in which two reviewers analysed the titles and abstracts of 25 randomly selected studies from the bibliographic search, was conducted. This pilot test helped determine whether the established eligibility criteria were well defined. The pilot test achieved a 92% agreement between reviewers, and the study selection continued to the next stage.

In this stage, two reviewers independently reviewed the titles, abstracts and keywords of studies found in the bibliographic search, applying the established eligibility criteria. The full texts of studies accepted in the previous stage were independently reviewed by two reviewers to include articles according to the inclusion criteria. Disagreements were resolved by a third reviewer or through discussion between the two reviewers.

In addition, a search in Google Scholar was conducted to include grey literature (unpublished), where the first 300 studies were reviewed according to Google's relevance algorithm. In this additional search, the descriptors were sought anywhere in the text without restricting to title, abstract or keywords.

Data extraction

Data from the studies included in the scoping review were extracted using a form developed by the reviewers, which is described in online supplemental material 2. This form was an Excel (Microsoft 365) table titled 'Data Extraction Instrument', individualised for each study to map its main information. The extraction format was developed based on recommendations from the JBI Review Manual,[25] as well as specific guidelines for this review.

Thus, this form contained the following information: study characteristics (eg, title, year of publication and country of origin), study sample (eg, sample size, sex and age), diagnostic equipment used (eg, type, commercial name, technical specifications differing from fixed equipment and body region examined), diagnostic service characteristics (eg, equipment transportation method, responsible professionals, type of residence where the service was conducted and service duration), examination conduct (eg, self-examination or team conducted the examination at location), health conditions diagnosed at home (eg, diagnosis, monitoring and health condition) and barriers and facilitators reported by users. The same two reviewers who conducted the previous stages tested the extraction form on two studies to ensure that all relevant results were extracted.

Data presentation and analysis

The data were presented in tables, charts and flow diagrams. The results included a numerical description of studies and a discussion of their data, covering the number of excluded studies and main reasons for exclusion, the number of included studies, study characteristics, types of HBD imaging/graph examinations performed, diagnosed health conditions and barriers and facilitators.

Data were presented as absolute and relative frequencies. For qualitative data, about the barriers and facilitators, a basic qualitative content analysis was conducted based on Pollock *et al*.[22] This approach follows the phases described by Elo and Kyngäs,[27] which involve four phases: preparation, organisation, reporting and abstraction. In the preparation phase, the extracted data were carefully reviewed to select units of analysis related to barriers and facilitators. During the organisation phase, the data were coded, and categories were developed inductively and refined to ensure coherence with the study's objective. The reporting phase detailed the categories and analysed patterns and relationships among them. Finally, in the abstraction phase, integrative concepts were constructed for a deeper understanding, resulting in the final categorisation of the findings.

For the identification of barriers and facilitators, the conceptual definitions proposed by Borges do Nascimento *et al* was used.[28] Their study describes barriers related to the use of digital health technologies in healthcare as including infrastructure challenges, such as limited connectivity and interoperability, resistance from professionals due to unfamiliarity and adaptation difficulties, privacy and data security concerns and insufficient training to use these tools effectively. Conversely, facilitators involve providing technical support to professionals, integrating digital tools into existing workflows, demonstrating clinical benefits and efficiency and promoting institutional policy support. The study by Borges do Nascimento *et al*[28] was used as a reference to support the conceptual framework on what constitutes barriers and facilitators. Data analysis in this review followed the content analysis method, as described in the previous paragraph. These conceptual definitions are aligned with the findings of the included studies, which also highlighted barriers and facilitators related to mobile diagnostic equipment and services in digital health.

RESULTS

Selection of evidence sources

Searches were conducted in six databases, identifying 1471 studies. Scopus yielded the most studies in the field

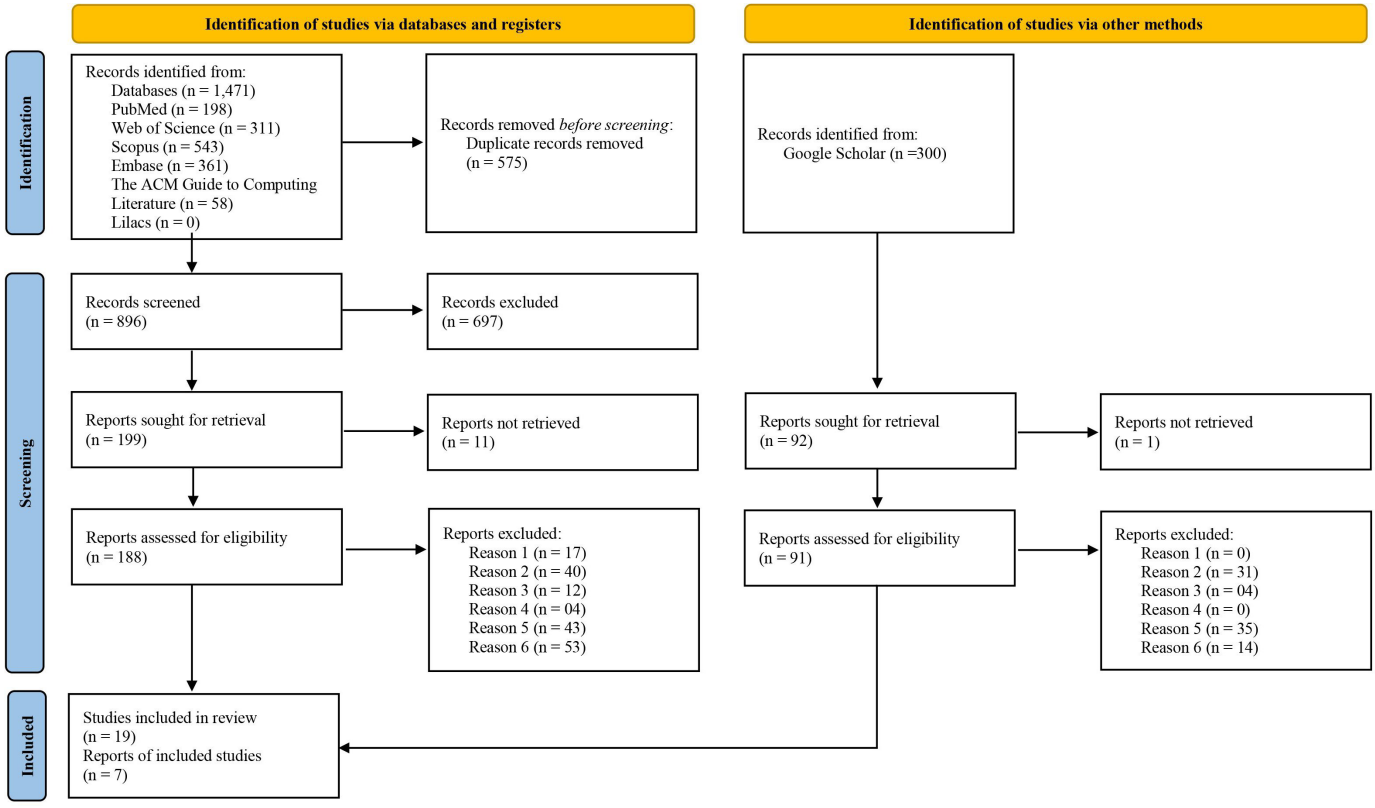

Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources. Reason 1: it is a literature review or a summary of a conference proceedings. Reason 2: did not perform a home-based diagnostic imaging/graph service. Reason 3: the home-based diagnostic imaging/graph procedure did not address health-related issues. Reason 4: the home-based diagnostic imaging/graph was not performed using portable equipment. Reason 5: did not conduct a home-based diagnostic imaging/graph service. Reason 6: did not report barriers or facilitators perceived by end users. Source: Page *et al*.[62]

of HBD imaging/graph services, followed by Embase, Web of Science, PubMed, The ACM Guide to Computing Literature and Lilacs. Additionally, an extra strategy was used with Google Scholar to retrieve the first 300 studies available in the grey literature.

Figure 1 presents the PRISMA flowchart, showing the selection outcomes of the evidence identified in this review. A total of 26 studies were included, with 19 from the primary search and seven from the additional strategy. The main reasons for exclusion were not performing an HBD imaging/graph diagnostic service, not offering an HBD imaging/graph service and lacking reports of barriers or facilitators experienced by end users.

Study characteristics

The studies cover a range of HBD imaging/graph services, including polysomnography (PSG) in 4 studies (15.4%), cardiotocography in 1 (3.8%), X-ray imaging in 11 (42.3%), ECG in 4 (15.4%), EEG in 4 (15.4%), thermographic camera in 1 (3.8%) and ultrasonography in 1 (3.8%). Some tests were self-administered, whereas others required an on-site team visit. Table 1 presents the titles of the 26 included studies, along with authors' names, year of publication, type of diagnostic test performed, how the test was conducted and the type of healthcare service provided in the studies.

The studies provided various ways to deliver HBD imaging/graph services, including monitoring, diagnosis and according to users' needs. Monitoring services assisted the patient in preventive health activities or an established health condition to track its progression. Diagnostic services focused on identifying a new health condition, and 'according to users' needs' services were typically provided in nursing homes for older people, where the necessary services (eg, chest X-ray imaging, spine X-ray imaging and ultrasonography) were identified based on the patient's needs at that time, which could be diagnosis or monitoring. Among professionals conducting the service, 13 studies (50.0%) did not report professionals were responsible. However, among those that did, the professionals conducting HBD imaging/graph services included primarily radiologic technicians/radiologists (23.1%), physicians (11.5%) and nurses (7.7%). Table 2 shows the characteristics of the included studies.

The studies in this review were conducted between 1998 and 2023, with 65.4% published after 2019 and originating from 15 countries, with the UK (15.4%),

Table 1 Characteristics of the studies

Study title	Reference	Author, year	Type of diagnostic test performed	How the examination was executed	Type of health service
Full polysomnography in the home	44	Fry *et al*, 1998	PSG	Self-examination	Sleep monitoring
Ten years' clinical experience with telemedicine in prenatal care in Hungary	45	Tõrõk, Turi and Kovács, 1999	Cardiotocography	Self-examination	Fetal monitoring
Positive experience of a mobile radiography service in nursing homes	29	Eklund *et al*, 2012	X-ray	Team went to the location	According to user needs
Real-time attended home-polysomnography with telematic data transmission	30	Bruyneel *et al*, 2013	PSG	Self-examination	Diagnosis of obstructive sleep apnoea
Usefulness of a portable internet-enabled ECG recording system for monitoring heart health among Japanese workers residing abroad	31	Kabe *et al*, 2014	ECG	Team went to the location	Cardiovascular disease monitoring
Mobile EEG in epilepsy	12	Askamp and Van Putten, 2014	EEG	Self-examination	Epilepsy monitoring
The role of nurses in e-health: The MobiGuide project experience	49	Parimbelli *et al*, 2016	ECG	Self-examination	Atrial fibrillation monitoring
Mobile X-ray service for nursing homes	32	Vigeland *et al*, 2017	X-ray	Team went to the location	According to user needs
Women's experience of wearing a portable fetal- electrocardiogram device to monitor small-for-gestational age fetus in their home environment	33	Kapaya, Dimelow and Anumba, 2018	ECG	Self-examination	Fetal monitoring
Is portable foetal electrocardiogram monitor feasible for foetal heart rate monitoring of small for gestational age foetuses in the home environment	34	Kapaya, Dimelow and Anumba, 2019	ECG	Self-examination	Fetal monitoring
Evaluation of the feasibility and preference of Nox-A1 type 2 ambulatory device for unattended home sleep test: a randomized crossover study	35	Yoon *et al*, 2019	PSG	Self-examination	Obstructive sleep apnoea monitoring
Configurable mobile system for autonomous high-quality sleep monitoring and closed-loop acoustic stimulation	46	Ferster, Lustenberger and Karlen, 2019	EEG	Self-examination	Sleep monitoring
Mobile radiography services in nursing homes-utilisation, costs and organisation	36	Kjelle, 2019	X-ray	Team went to the location	According to user needs
Mobile X-ray Outside the Hospital vs X-ray at the Hospital Challenges Exposed in an Explorative RCT Study	9	Toppenberg *et al*, 2020	X-ray	Team went to the location	According to user needs
Stress detection and monitoring based on low-cost mobile thermography	48	Baran, 2021	Thermographic Camera	Team went to the location	Stress diagnosis and monitoring
Clinical screening tools for obstructive sleep apnea in a population with atrial fibrillation: A diagnostic accuracy trial	37	Mohammadieh *et al*, 2021	PSG	Self-examination	Diagnosis of obstructive sleep apnoea
Exploring the patient perspectives of mobile X-ray in nursing homes - A qualitative explorative pilot study	20	Jensen *et al*, 2021	X-ray	Team went to the location	According to user needs
Home mobile radiography service in the COVID-19 era	47	Raiano *et al*, 2021	X-ray	Team went to the location	COVID-19 monitoring
Investigating neural dynamics in autism spectrum conditions outside of the laboratory using mobile electroencephalography	38	Giannadou *et al*, 2022	EEG	Self-examination	According to user needs

Continued

Table 1 Continued

Study title	Reference	Author, year	Type of diagnostic test performed	How the examination was executed	Type of health service
Residents' perspectives of mobile X-ray services in support of healthcare-in-place in residential aged care facilities: a qualitative study	[19]	Dollard *et al*, 2022	X-ray	Team went to the location	According to user needs
Taking acute medical imaging to the patient, the domiciliary based X-ray response team	[39]	Mark, Henderson and Brealey	X-ray	Team went to the location	According to user needs
Mobile Self-Operated Home Ultrasound System for Remote Fetal Assessment During Pregnancy	[40]	Hadar *et al*, 2022	Ultrasound	Self-examination	Fetal monitoring
Satisfaction of Patients Examined with Mobile X-Ray vs X-Ray at the Hospital - A Randomized Controlled Trial	[41]	Toppenberg, Nielsen and Damsgaard, 2022	X-ray	Team went to the location	According to user needs
Day-to-day individual alpha frequency variability measured by a mobile EEG device relates to anxiety	[42]	Sidelinger *et al*, 2023	EEG	Self-examination	Individual alpha frequency monitoring and anxiety
How to set up a mobile X-ray unit in the community - Implementation initiatives for patient-centred care	[50]	Andersen *et al*, 2023	X-ray	Team went to the location	According to user needs
Mobile X-ray services in nursing homes as an enabler to healthcare-in-place for residents: informal carers' views	[43]	Dollard *et al*, 2023	X-ray	NR	According to user needs

Source: Developed by the author (2025).
ECG, electrocardiogram; EEG, electroencephalogram; NR, not reported; PSG, polysomnography.

Denmark (15.4%), Australia (11.5%), USA (7.7%), Italy (7.7%) and Norway (7.7%) publishing the most studies on HBD imaging/graph services.

Regarding the study methodology, 26.9% followed a cross-sectional design, whereas 73.1% used a longitudinal design. Sample sizes ranged from 1 to 10 participants (15.4%), 11 to 20 (15.4%), 21 to 40 (15.4%), 50 to 70 (26.9%), 71 to 263 (23.1%) and 3.8% did not report sample size. Approximately 46.2% of the studies included both male and female participants, with age averages ranging from 11 to 86 years. Of these, 26.9% had a mean age ranging from 53 to 86 years, whereas 46.2% did not report participants' mean ages.

Twenty-two body areas were examined, with the most common being the chest (26.9%), head (23.1%) and abdomen (15.4%). Some studies evaluated more than one body area, and around 23.1% did not specify the body area analysed. Of the 26 studies, 19 (73.1%)[9 12 19 20 29–43] were using questionnaires to identify user needs for HBD imaging/graph services. Seven studies (26.9%)[30 37 39 44–47] reported that mobile equipment had the same or better accuracy to traditional hospital equipment, and none of the 26 studies reported using artificial intelligence to analyse the images obtained from in-home diagnostic services.

Regarding image transmission in in-home diagnostic examinations, 16 studies (61.5%)[9 12 19 20 33–38 40 41 43 44 46 48] did not report whether images were sent via telemedicine to a professional, and 4 (15.4%)[29 31 32 45] explicitly stated that they were not sent. However, six studies (23.1%)[30 39 42 47 49 50] did transmit images via telemedicine. For the transportation of diagnostic equipment to patients' homes, 20 studies (76.9%)[9 12 19 31–37 39–46 48 49] did not explicitly report transportation methods. In five of these studies,[33–35 42 44] participants collected the equipment from the research laboratory and returned it, or the researcher collected it from the participant's home after data collection. In six studies (23.1%),[20 29 30 38 47 50] equipment transportation involved the technician driving a certified vehicle, like a van, to the participant's residence.

The most common locations for in-home diagnostic services were participants' own homes in 17 studies (65.4%),[12 30 31 33–35 37–40 42 44–49] followed by nursing homes in 10 (38.5%),[9 19 20 29 32 36 39 41 43 50] and, in one case, a hotel for participants who could not return home but could stay outside of the lab. About 50.0% (13 studies)[9 19 31 32 36 39 41 43 45 47–50] did not report the duration of the in-home diagnostic service. In the remaining 13 studies, 4 reported a one-night duration,[30 35 37 44] while others varied from 14 nights, 4 weeks, 25 min, 3, 7 or 20 hours, 7–14 days, 2 hours and 10 min, or once a week during the study's data collection period.[12 20 29 33 34 38 40 42 46]

Table 2 Characteristics of the included studies

Variables	N	%
Year of publication		
1998	1	3.8
1999	1	3.8
2012	1	3.8
2013	2	7.7
2014	1	3.8
2016	1	3.8
2017	1	3.8
2018	1	3.8
2019	4	15.4
2020	1	3.8
2021	4	15.4
2022	5	19.2
2023	3	11.5
Location: country		
United Kingdom	4	15.4
Denmark	4	15.4
Australia	3	11.5
USA	2	7.7
Italy	2	7.7
Norway	2	7.7
Belgium	1	3.8
South Korea	1	3.8
Finland	1	3.8
Netherlands	1	3.8
Hungary	1	3.8
Israel	1	3.8
Japan	1	3.8
Poland	1	3.8
Switzerland	1	3.8
Methodology		
Cross-sectional	7	26.9
Longitudinal	19	73.1
Sample size		
1–10	4	15.4
11–20	4	15.4
21–40	4	15.4
50–70	7	26.9
71–80	1	3.8
100–110	2	7.7
120–150	2	7.7
263	1	3.8
NR	1	3.8
Sex		
Female and male	12	46.2
Female only	4	15.4
Male only	2	7.7
NR	8	30.8
Average age of participants (years)		
11	1	3.8
28–33	3	11.5
44–50	3	11.5
53–66	3	11.5
80–86	4	15.4
NR	12	46.2

Source: Developed by the author (2024).
NR, not reported.

Barriers and facilitators related to the performance of home-based diagnostic imaging/graph

According to the basic qualitative content analysis, the barriers were separated into seven categories: discomfort and difficulties (related to the exam), communication and relationship challenges (related to professionals), equipment issues and difficulties, procedural issues and adverse events, transportation and logistical conditions, psychological aspects and economic and administrative issues. Figure 2 shows the subcategories of barriers identified in each of the included studies.

Discomfort and difficulties are related to conducting the examinations and were identified in the studies.[12 19 30 33–35 38 40] This subcategory includes barriers such as activity restrictions, discomfort sensations (related to equipment sounds) or physical discomfort (skin irritation and weight of the device on the body), sleep disruption and interference with daily activities.

Communication and relationship difficulties are related to the professionals responsible for performing HBD imaging/graph examinations and were observed in the studies.[9 19 20 36 43 50] This subcategory pertains to the relationship between the patient and the professional in charge, and it includes issues such as aggressive behaviour or lack of cooperation from the patient or concerns about patient safety.

Equipment issues and difficulties were identified in the studies.[9 19 33 35 40 43 44] This subcategory involves concerns related to the performance of HBD imaging/graph examinations, such as data acquisition, patient data security, data quality, need for a caregiver or family member to assist the patient during the exam and equipment design issues not suited to patient needs. Additionally, equipment malfunctions, lack of perceived benefit compared with traditional equipment and patients' resistance due to unfamiliarity with mobile imaging/graph devices and excessive feedback were reported.

Procedural issues and adverse events were identified in the studies.[12 20 36 38 40 44] These issues involve examination

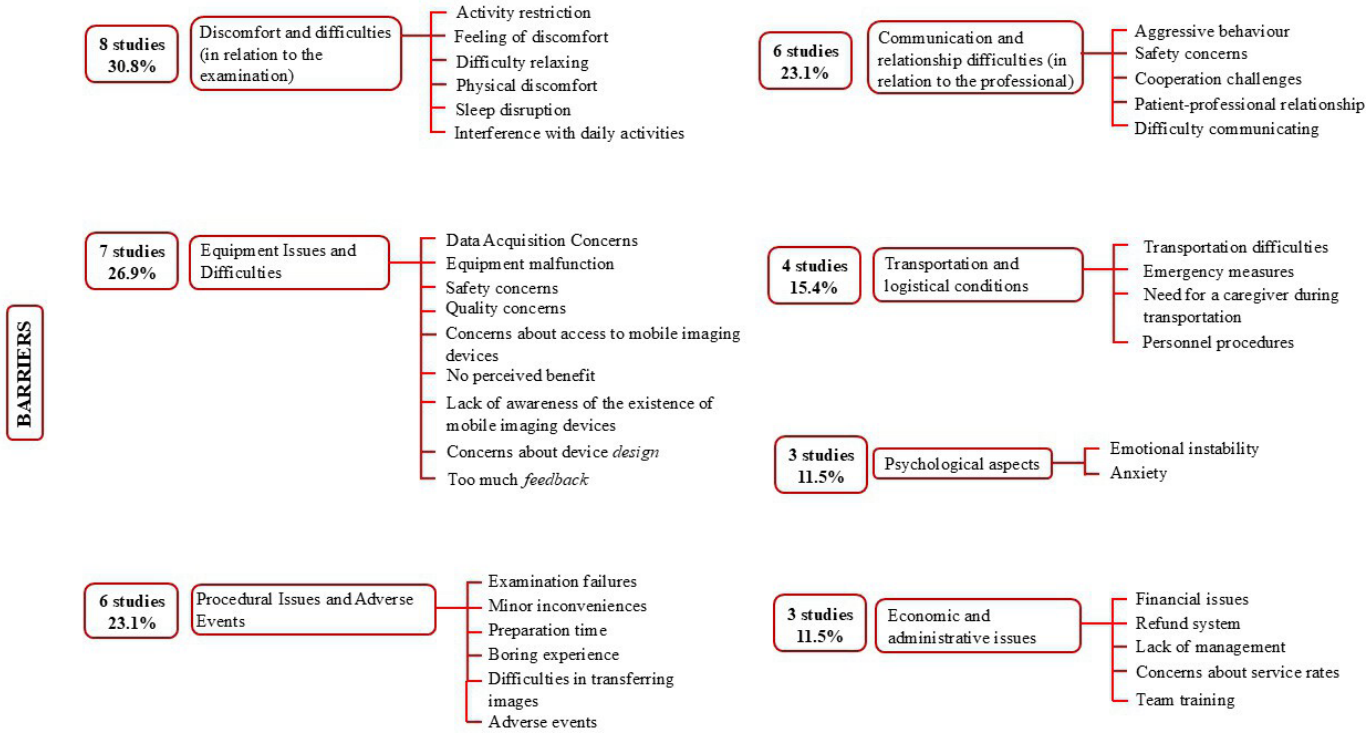

Figure 2 Subcategories of barriers identified in each of the included studies. Source: developed by the author (2024).

failures, minor inconveniences, equipment preparation time, patient complaints of boredom or adverse events (such as device-induced warming) during examinations. Additionally, difficulties in transferring images, such as electronic communication gaps between hospitals and nursing homes, hampered X-ray image transfer for hospital analysis.

Transportation and logistical conditions were identified in the studies.[9 35 43 44] This subcategory addresses difficulties in transporting diagnostic imaging/graph equipment to the patient's home or the need to transport the caregiver in case of emergencies, as well as procedures for personnel in case emergency measures are needed.

Psychological aspects were addressed in the studies[12 20 33] and are related to the emotional instability or anxiety of patients and their caregivers or family members during the HBD imaging/graph examinations.

Economic and administrative issues were identified in the studies.[19 36 43] These relate to financial problems, reimbursement systems or fees associated with HBD imaging/graph examinations. Concerns included payment requirements, which were especially worrisome for older patients who often reported lacking financial control. Additionally, caregivers expressed concerns about managing HBD imaging/graph services and training personnel responsible for these services.

According to the basic qualitative content analysis, the facilitators were separated into seven categories: comfort and environment, equipment usability, data quality and accuracy, service logistics, patient and caregiver satisfaction and well-being, collaboration and communication and economic and administrative aspects. Figure 3 shows the subcategories of facilitators identified in each of the included studies.

Comfort and environment were identified in the studies.[12 19 20 29–31 33–35 37–39 41 43 44 48 50] This subcategory includes factors related to conducting HBD imaging/graph services, such as comfort, relaxation, greater privacy and convenience in a familiar, calm environment that promotes patient safety.

Equipment usability was identified in the studies[30 31 33 34 38 40 42 43 46] and pertains mainly to equipment usability. This includes the ease of application, use and set-up of HBD imaging/graph devices, as well as the simplicity of ultrasound gel. Participants were satisfied with the equipment's interface, describing it as 'engaging', with interactive configurations and playful design, and some devices incorporated rewards and incentives.

Data quality and accuracy were found.[34 35 42 44–46] This category covers the quality and accuracy of data obtained from HBD imaging/graph examinations, such as minimal data loss, high-quality data, effective sensor use and accurate detection equivalent to traditional hospital equipment.

Service logistics was identified in studies[19 29 32–34 36 42 46 49] and relates to the portability and non-intrusive application of HBD imaging/graph equipment, allowing patients to continue daily activities. Studies also reported factors such as avoiding patient transportation, increasing accessibility and immediate data collection with real-time information.

Satisfaction and well-being were identified in studies.[12 20 29–31 35 39–41 43 47] Both patient and caregiver satisfaction and well-being were observed, including better sleep quality during HBD PSG, with fewer nighttime

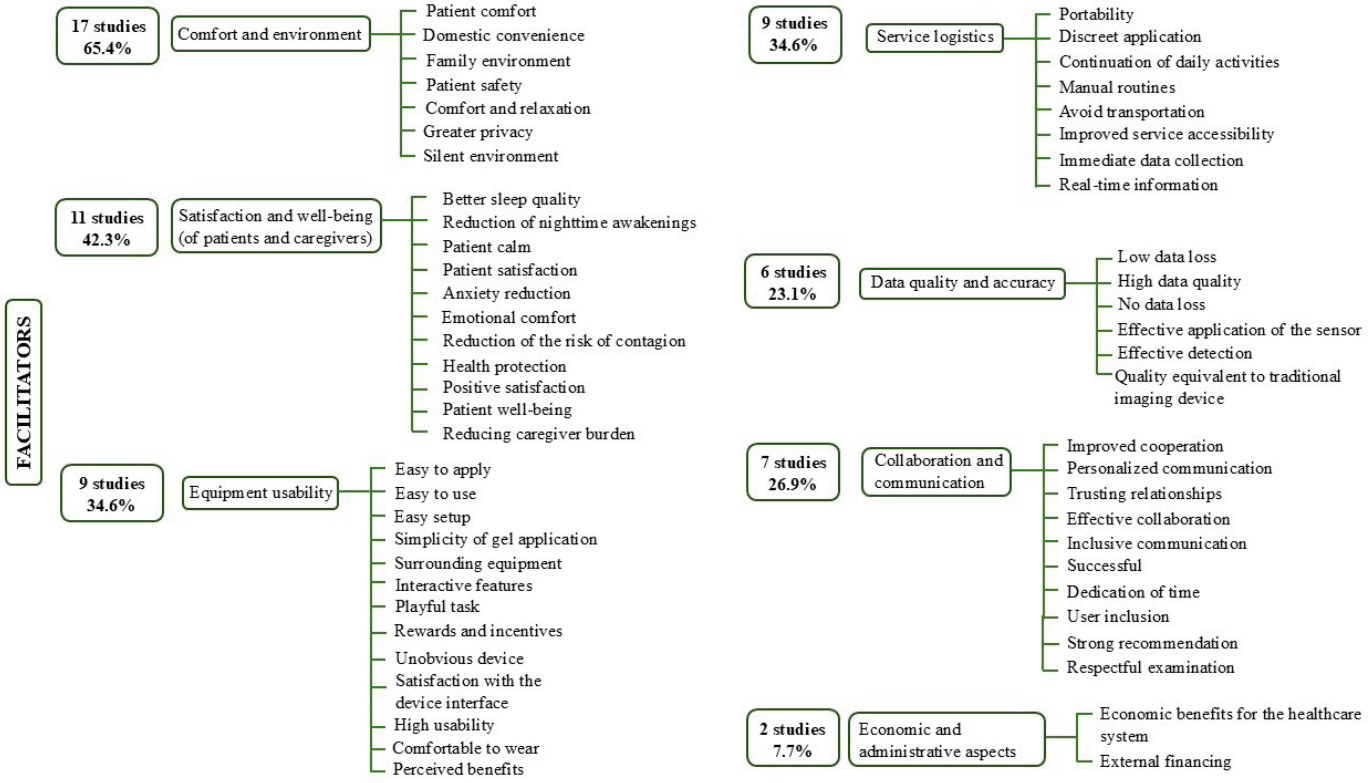

Figure 3 Subcategories of facilitators identified in each of the included studies. Source: developed by the author (2024).

awakenings. Studies noted greater calm, reduced anxiety and emotional comfort, as well as decreased caregiver burden and lower risk of health condition transmission.

Collaboration and communication were observed in studies.[20 36 38–41 50] This category covers the patient–professional relationship that fosters positive experiences, including good cooperation, personalised and inclusive communication, trust, successful networking, professionals' dedication to patients, respectful examination, effective patient cooperation and strong service recommendation.

Economic and administrative aspects were identified in studies[36 43] and include external funding and economic benefits for the healthcare system related to conducting HBD imaging/graph services.

Results by the type of home-based diagnostic imaging/graph examination

To gather key findings by the type of HBD imaging/graph examination, mind maps were created for each examination type identified in the studies. A total of seven types of HBD imaging examinations were identified.

X-ray imaging was conducted in 11 of the 26 included studies. These studies indicated that this type of HBD imaging/graph examination provides quality comparable to traditional X-ray examinations. These X-ray examinations were conducted on various skeletal regions. They were performed by trained professionals, primarily radiographers, in accordance with national regulations. In certain settings, doctors may also carry out or supervise these procedures, depending on the country's professional guidelines and institutional protocols. The studies that employed X-ray imaging were conducted in patients' homes or nursing homes where they lived, and it was used for several purposes, such as monitoring health conditions like COVID-19, or when the patient needed an X-ray imaging primarily for falls and fractures. The target populations were groups in active retirement, frail and dependent. The barriers identified in relation to X-ray imaging in these studies included communication difficulties with the professional, equipment issues and psychological aspects. The facilitators highlighted were comfort and environment, patient and caregiver satisfaction and well-being and collaboration and communication.

PSG was used in four of the 26 included studies. These studies indicated that this type of HBD imaging/graph examination has quality comparable to traditional PSG. This examination was conducted mainly on the head, face, trunk and upper limbs of the patients and could be self-administered or conducted by a sleep technician. PSG studies were performed in participants' homes or in a hotel room, taking place over one night's sleep, and were used to monitor obstructive sleep apnoea or simply to monitor sleep. The target populations were groups in the main working phase and active retirement. The barriers identified for PSG in these studies included discomfort and difficulties with the examination, equipment issues, procedural issues and adverse events and transportation and logistics conditions. The facilitators

included comfort and environment, equipment usability, data quality and accuracy and patient and caregiver satisfaction and well-being.

ECGs were used in four of the 26 included studies. These studies reported that this type of HBD imaging/graph examination provides quality comparable to traditional ECG examinations. This examination was conducted in areas of the body such as the abdomen or placed in the patient's pocket area. This examination was performed by a nurse, cardiovascular specialist or occupational physician. Studies using ECGs were conducted in patients' homes. The target populations were groups in the main working phase and active retirement, and they were used to check fetal heart rate, atrial fibrillation or monitor cardiovascular diseases. Barriers to ECG usage identified in the studies included discomfort and difficulties with the examination, equipment issues and psychological aspects. Facilitators included comfort and environment, equipment usability, service logistics and patient and caregiver satisfaction and well-being.

EEGs were used in four of the 26 included studies. These studies indicated that this type of HBD imaging/graph examination provides quality comparable to traditional EEG examinations. The examination was conducted only on the face or head of patients, administered by a responsible researcher, through self-examination, or by a clinical neurophysiologist, with the goal of monitoring sleep, tracking epilepsy cases or monitoring individual alpha frequency and anxiety. EEG studies were conducted in patients' homes, and the target populations were groups in the formative period of the main working phase and active retirement. Barriers to EEG usage included discomfort and difficulties with the examination, procedural issues and adverse events and psychological aspects. Facilitators included comfort and environment, equipment usability, data quality and accuracy, service logistics, patient and caregiver satisfaction and well-being and collaboration and communication.

Cardiotocography was used in one of the 26 included studies. This study stated that this type of HBD imaging/graph examination has quality comparable to traditional cardiotocography examinations. The examination was conducted in the uterine area of the patient by a midwife and a doctor. The cardiotocography study was conducted in the participant's home, targeting the population group in the main working phase, and was used to prevent preterm birth and reduce perinatal mortality. The study did not indicate barriers regarding the use of this HBD imaging/graph equipment, and as a facilitator, the subcategory of data quality and accuracy was noted.

A mobile thermographic camera was used in one of the 26 included studies. In this study, the examination was conducted at the patient's home to check stress levels. The camera was positioned on the patient's face, which fell under target populations in the main working phase and active retirement. No barriers were identified in this study regarding the use of the mobile thermographic camera. However, the main facilitators addressed were comfort and environment.

Ultrasonography was used in one of the 26 included studies. The examination was conducted in the patient's home and could be conducted as a self-examination, but with the assistance of an obstetrician-gynaecologist or an experienced ultrasound technician. The examination targeted the uterine area to detect possible severe maternal or foetal adverse events. The target population was the group in the main working phase. The barriers identified for the use of ultrasonography included discomfort and difficulties with the examination and procedural issues and adverse events. The facilitators noted were equipment usability, data quality and accuracy, patient and caregiver satisfaction and well-being and collaboration and communication.

Mind maps for each type of HBD imaging/graph are available in online supplemental material 3. Although seven different examinations were identified, the barriers and facilitators fell into the same subcategories, with differences among examinations primarily related to the objective of each examination, target population and body region involved in the procedure.

DISCUSSION

This review identified 1471 studies on HBD imaging/graph services, with 26 studies included. These studies were published between 1998 and 2023 and conducted in 15 different countries. Various types of diagnostic imaging/graph examinations were studied, including PSG, cardiotocography, X-ray imaging, ECGs, EEGs, mobile thermographic cameras and ultrasonography. Barriers and facilitators for each of these 26 studies were identified, concerning the use of these diagnostic imaging/graph examinations at home. The main barriers included discomfort and difficulties, equipment issues and problems with procedures and adverse events, whereas the main facilitators were comfort and environment, satisfaction and well-being, equipment usability and service logistics.

Most studies on HBD imaging/graph were published after 2019, likely driven by technological advances, new digital health solutions and the COVID-19 pandemic, which underscored the importance of remote diagnostics to reduce virus transmission and maintain healthcare during social distancing. These factors increased the interest in and the need to develop home diagnostic services to meet new global demands.[51] The geographic diversity of studies, conducted in 15 different countries, directly affects the analysis of results, as each country's specific factors, such as cultural, technological, economic, political and educational aspects, must be considered.[1 52]

This study showed that X-ray examinations are the most commonly performed HBD imaging/graph examination. This may be mainly due to the relative simplicity of portable versions of X-ray equipment and the minimal preparation required, making it a practical option for

monitoring health conditions.[9] Ledur Vaucher[53] argued that portable equipment such as X-ray offers several advantages, particularly for individuals with mobility issues, allowing efficient diagnosis at home without requiring the patient to travel to a hospital or diagnostic centre.

ECGs, PSG and EEGs are also frequently used in HBD imaging/graph services and are often applied as self-administered tests. Portable versions of these devices allow for self-application with proper guidance. However, despite the good accuracy provided by these portable devices, self-application remains challenging owing to incorrect electrode placement, which can compromise result quality.[54] This highlights the importance of involving qualified professionals in healthcare services, a factor that can directly affect the examination process and outcomes.

In this study, most of the examinations were conducted either in patients' homes or in nursing homes, demonstrating the feasibility of this practice. Therefore, users' needs must be considered by promoting personalised, accessible and inclusive care, especially for individuals with reduced mobility. Understanding these demands allows for the improvement of equipment and the development of usage guidelines, facilitating treatment adherence and health monitoring.[55]

Analysing barriers related to HBD imaging/graph services, the main categories identified by patients were discomfort and difficulties, equipment issues and problems with procedures and adverse events, especially concerning examinations such as PSG and ultrasonography. When conducted outside of clinical settings, patients encountered challenges related to a lack of immediate technical support and difficulty in configuring or operating the devices effectively. Meyerheim *et al*[56] argued that despite implementation challenges, digital health solutions hold great potential for patient-centred care. However, they recommend using these solutions with efficient communication among all parties involved to facilitate integration into clinical practice.

Discomfort is also a factor in PSG, as the examination requires the use of multiple sensors on the body overnight. Although many patients reported being comfortable in conducting the test at home in their own bed, equipment-induced discomfort was still noted. This presents a challenge, as if the examination causes discomfort at home, conducting it in a lab or unfamiliar environment may increase discomfort and negatively affect the test results. Ferretti *et al*[57] found that when performed at home over multiple nights, PSG provided better diagnostic accuracy than conventional sleep evaluations.

ECGs were also noted under barriers, as patients reported discomfort from the wires, particularly when using the bathroom. Additionally, this examination was noted under the psychological aspects category, which, though not highly prevalent, is significant. This was highlighted by a family member of a patient who expressed concern over information access. They noted that pregnant patients are often anxious, which could worsen with excess examination-related information. Pillemer *et al*[58] argue that direct access to examination results can cause anxiety and lead to increased medical consultations, underscoring the need to involve qualified professionals in healthcare service processes.

Conversely, when analysing facilitators for HBD imaging/graph services, some of the most prevalent categories among the studies emerged. Comfort and environment were a notable category, as patients viewed having these services at home or familiar locations, such as hotels, as enhancing comfort and reducing stress, especially for those requiring ongoing monitoring. This is beneficial for PSG and EEG examinations, where stress reduction contributes to result accuracy. Da Silva Souto *et al*[59] compared the use of mobile PSG and EEG for sleep analysis and concluded that using self-applicable, discreet sensors could improve sleep diagnostic at home and be a comfortable option for long-term monitoring for patients with neurological and psychiatric issues.

In contrast, patient and caregiver satisfaction and well-being highlighted the specialisation of professionals as a key point in improving home-based care. Studies indicated that well-established communication between patients and healthcare teams/stakeholders could increase satisfaction among both patients and caregivers, creating a secure and trusting environment during the examination. Cunha *et al*[60] argue that for effective home care, multiple factors must be considered. Healthcare professionals must consider patient safety and provide emotional and social support while involving patients in care decisions. Caregivers and family members also need to understand home care processes and the use of remote monitoring technologies.

Finally, other frequently mentioned categories in the studies were equipment usability and service logistics, as improvements and adaptations in device design enhance patient autonomy, especially in self-administered examinations or examinations requiring minimal operation, such as mobile thermographic cameras. The portability and ease of use make the examinations less intrusive and more efficient. This aligns with findings of Tase *et al*,[61] who noted challenges in using medical devices at home. They see a need for advances to bridge knowledge gaps and improve post-market testing, emphasising design and equipment safety, as well as patient satisfaction and treatment adherence. The importance of including patients directly in these tests is highlighted.

The literature review by Kjelle and Lysdahl[24] identified outcomes associated with the use of mobile X-ray services in nursing homes, such as increased access, avoiding the need for transportation to a hospital, reduced hospitalisations, decreased patient discomfort and cost savings. These findings are similar to some of the results of the present review, which covers different types of HBD imaging/graph performed at the patient's home. They identified that transportation and logistical conditions can be barriers, whereas patient comfort and satisfaction

from not needing to travel, avoidance of hospital transfers and economic benefits emerged as facilitators.

A limitation of this study was the possible loss of studies owing to the search being restricted to studies specifically addressing the barriers and facilitators associated with HBD imaging/graph services. Another limitation was the difficulty in contacting authors to request full access to studies that could not be fully analysed. Some material may have been missed owing to a lack of access to these studies. As a comprehensive mapping of all literature on the topic, this review did not assess study quality. Future studies could assess the quality of studies in a systematic review and compare different countries or regions to examine economic and cultural influences.

CONCLUSION

This review identified seven types of HBD imaging/graph examinations performed at home, with X-ray imaging, ECGs, EEGs and PSG as the main ones. This scoping review of the literature allowed mapping and systematising the barriers and facilitators in performing these examinations at home, encompassing factors that influence the provision of this type of service, such as logistics, equipment used, comfort of the home environment and patient well-being. Additionally, this review allowed for the identification of gaps in the literature, providing a solid foundation for future research and potentially supporting the formulation of more appropriate and accessible public policies and practices.

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Patient consent for publication Not applicable.

Ethics approval As this study is a literature review, it does not require approval from the Research Ethics Committee. Although ethics approval is not applicable to this type of study, it is part of a broader project in Brazil entitled 'Health2Home: Diagnostic imaging at home for older users', which was approved by the Ethics Committee of the Federal University of São Carlos (cephumanos@ufscar.br) under approval number 6.454.104. And one of the authors is a member of the Research Ethics Committee at the Federal University of São Carlos (castro@ufscar.br).

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