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Barriers and facilitators of patient access to medical devices in Europe: A systematic literature review

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ABSTRACT

A large number of medical devices (MDs) is available in Europe. Procedures for market approval and reimbursement have been adopted over recent years to promote accelerating patient access to innovative MDs. However, there remains uncertainty and non-transparency regarding these procedures. We provide a structured overview of market approval and reimbursement procedures and practices regarding access to MDs in the EU.

Market approval procedures were found to be uniformly described. Data on reimbursement procedures and practices was both heterogeneous and incomplete. Time to MD access was mainly determined by reimbursement procedures. The influence of the patient on time to access was not reported. Prescription practices varied among device types.

Barriers to and facilitators of early patient access that set the agenda for policy implications were also analyzed. Barriers were caused by unclear European legislation, complex market approval procedures, lack of data collection, inconsistency in evidence requirements between countries, regional reimbursement and provision, and factors influencing physicians' prescription including the device costs, waiting times and hospital-physician relationships. Facilitators were: available evidence that meets country-specific requirements for reimbursement, diagnosis-related groups, additional payments and research programs.

Further research needs to focus on creating a complete overview of reimbursement procedures and practices by extracting further information from sources such as grey literature and interviews with professionals, and defining clear criteria to objectify time to access.

1. Introduction

Medical devices (MDs) play a crucial role in healthcare provision for patients in the European Union (EU). Approximately 500,000 different MDs are available on the EU market, covering a broad range of technologies, from wound bandages to implantable devices, serving multiple purposes, including the diagnosis of disease, prevention, treatment, rehabilitation, and increasing the quality of life of patients [1,2].

A summary of what the World Health Organization (WHO) defined as medical device is: any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material orsimilar or article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s) of: including monitoring, alleviation of disease, alleviation of or compensation for an injury, investigation, replacement, modification, or support of the anatomy or of a physiological process, control of conception, disinfection of medical devices, providing information by means of in vitro examination of specimens derived from the human body; and does not achieve its primary intended action by pharmacological, immunological or metabolic means, in or on the human body, but which may be assisted in its intended function by such means [3].

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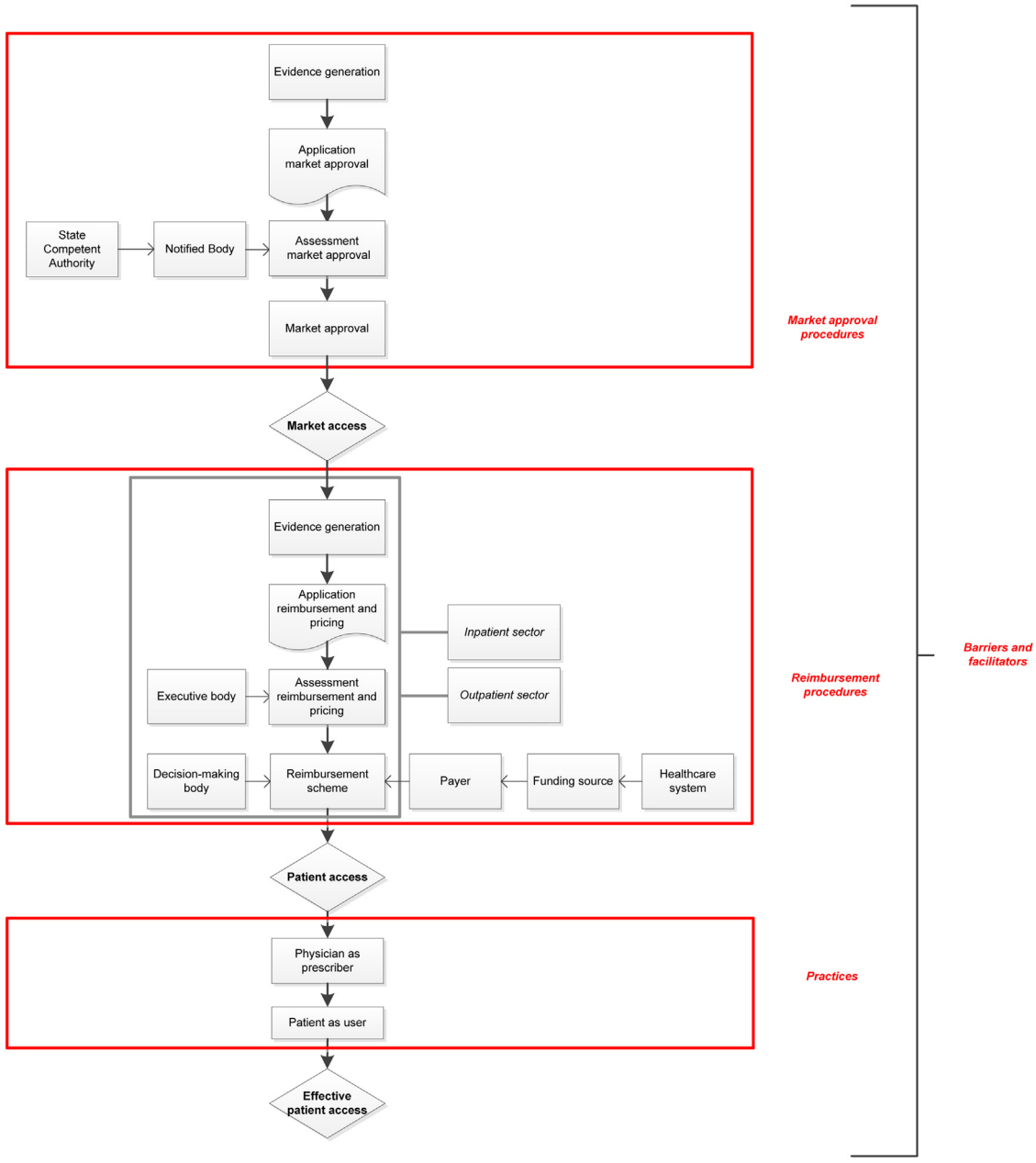

Fig. 1. Generalized model concerning procedures and practices towards effective patient access to medical devices. Applications are displayed with document shapes (curved), procedures and authorities with rectangles, and access types that are products resulting from different procedures with rhombuses. The arrows in bold indicate the different steps of the process. Other arrows point from the components that have an influential role to the components that are influenced. The red contours capture the different market approval and reimbursement procedures and practices, and the grey contours the inpatient and outpatient sector (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Although MDs are essential in delivering healthcare, it may take up to six years for a MD to go from bench to the patient's bedside, termed 'effective patient access' [4]. Effective patient access is defined in this study as: the realization of access to MDs for patients. The pathway towards effective patient access is a stepwise process comprising market approval and reimbursement procedures, both consisting of multiple components (e.g. evidence generation and pricing), and prescription practices (Fig. 1) [5,6].

In the EU, market access to MDs has been governed by EU Directive 2007/47/EC (as amended) relating to MDs and active implantable medical devices (AIMDs), and Directive 98/79/EC concerning in vitro diagnostics [7]. These directives were implemented into national legislation and specified requirements at an EU level for the pre- and post-market approval of MDs with the aim of securing patients' safety [8–10]. In April 2017, new MD regulations (Regulation (EU) 2017/745 and Regulation (EU) 2017/746) were adopted [11]. Subsequently, implementation in the EU member states will be achieved in the coming years. Until now, requirements concerning reimbursement procedures have been left to decide at the national level [9].

MDs require a Conformité Européenne (CE) mark, indicating a successful conformity assessment of the device, before it may be placed on the EU market. As the process to obtain market access, starting after completion of CE mark application and involves assessment of device's safety and performance, is estimated to take a maximum of three months, subsequent procedures and practices regarding reimbursement (including evidence generation) and prescription of MDs respectively are considered to play

a dominant role in effective and timely patient access [4,12]. Little information is currently available on reimbursement procedures and practices, due to language barriers, incomplete information, non-transparency, and both unclear and rapidly changing regulations [13–15]. Furthermore, manufacturers often have difficulty understanding and applying such regulations, during the process of diffusion of devices [16].

To our knowledge, there is no systematic overview in the literature on market approval and reimbursement procedures, that includes evidence requirements, and prescription practices leading to effective patient access [17]. Providing a comprehensive overview of current procedures regarding market approval and reimbursement of MDs in the EU member states will result in more transparency and could lead to a better understanding of such procedures for medical device companies, health policy makers and healthcare provider introducing MDs in practice in the EU [15].

Therefore, we framed the research question as: 'What are the country-specific procedures involved in obtaining effective patient access to MDs in various EU member states, and what are the barriers and facilitators related to these procedures?'. The aim of this study is to get an overview — through a systematic literature review — of current market approval and reimbursement procedures and practices involved in obtaining effective patient access to MDs in several EU member states. This includes all MDs irrespective of the risk class and use (inpatient or outpatient care) with the exception of drug delivery devices, in vitro diagnostics and implantable powered electronic devices). Secondly, we will identify barriers to and facilitators of early effective patient access. From the results, we will come up with policy recommendations.

Box 1: Inclusion and exclusion criteria for the systematic review on effective patient access to medical devices in European countries.

Inclusion criteria

1 The objective of the publication concerns:
  i market approval procedures of medical devices and/or
  ii reimbursement procedures of medical devices and/or
  iii prescription of medical devices by the physician or utilization by the patient
2 The information is country-specific for one or more European countries
3 The information reliably reflects current practice*

Exclusion criteria

1 The objective of the publication concerns:
  i drug delivery devices, in vitro diagnostics or implantable powered electronic devices
  ii specific examples of medical devices
2 The information concerns Europe (in general) without country-specific information
3 The information does not reliably reflect current practice*

* Publications were considered to reliably reflect current practice when the content corresponded to included publications from 2013 until 2015 or up-to-date information on websites published by health authorities.

2. Materials and methods

2.1. Search strategy

To identify the most relevant publications that reliably reflect current practice, we performed a systematic literature search in MEDLINE/PubMed, Embase (Ovid) and Scopus from January 2000 to December 2015. The following keywords were applied in various forms during the search strategy: ('medical devices' AND 'regulation' AND ('costs' OR 'reimbursement') AND 'Europe' (including individual country names)) OR ('device' [title] AND ('regulat*' [title] OR 'reimbursement' [title]) AND 'Europe' (including individual country names)). The full detailed list of keywords form Table 1 in Appendix A (Supplementary Material).

2.2. Publication selection

The inclusion and exclusion criteria (Box 1) were determined and agreed a priori. Publications were included if the main objective was to inform or discuss market approval and/or reimbursement procedures, and practices of MDs in EU member states, and/or barriers to and facilitators of early effective patient access. All languages were considered. There was no limitation on the type of publication, which included editorials, book chapters, and conference abstracts that led to posters and presentations. Authors of conference papers or unavailable publications were contacted for full text publications. Conference papers of which the full text of the article was also included in the search were considered as duplicate publications and were therefore excluded. Furthermore, publications that did not reliably reflect current practice were considered not relevant and thus excluded from this study. Publications were considered to reliably reflect current practice when the content corresponded to included publications from 2013 until 2015. In case of doubt, the author was contacted to verify if the information that he or she reported reliably reflected current practice, and the content of the publication was compared to up-to-date information on websites published by health authorities. In addition, publications focusing only on devices that originally fell under a separate directive, such as in vitro diagnostics (Directive 98/79/EC), implantable powered electronic devices (Directive 90/385/EEC), and drug-delivery devices (assigned as medicinal products: Directive 2004/27/EC), were excluded because procedures and practices may differ from those of the MDs governed by the EU Directive 2007/47/EC which we focus on in our review [10,11,18,19]. Also, publications concerning the EU in general (without mentioning country-specific information) were excluded. Quality assessment was not relevant to this study as identifying forms of bias was not indicated.

Screening on title and abstract was carried out by the first author. The second author screened a random sample of 10% of all publications. The content of full texts was assessed on eligibility by the first author and a random sample of 10% by the second author [20]. In addition, publications of which the suitability was questioned by the first author were assessed and discussed with the second author. If there was an agreement rate of $\geq$95%, it had been decided that optimal agreement had been established in the screening process. In both screening processes, both authors discussed their choices with the last author in case of disagreement. The judgment of the last author was decisive in determining inclusion or exclusion.

2.3. Data extraction and analysis

Data extraction was performed by the first author. Publications reported in other languages than English or Dutch were translated by native speakers experienced in the specific field of research. Based on country-specific healthcare systems roadmaps, we created a generalized access model conceptualizing the MD pathway towards effective patient access and verified the components of the model in this study during the full text assessment (Fig. 1) [21]. This model was used to extract key data on [1]: current market approval procedures [2]; reimbursement procedures [3]; and prac-

tices of MDs in achieving market access, patient access and effective patient access respectively. In addition [4], barriers to and facilitators of early effective patient access, defined as factors that hinder or promote time to effective patient access respectively, were identified and listed in the Results section. Barriers and facilitators were described in the literature whether or not those specific terms were used. Data on these four aspects were extracted from the included publications. The data was extracted in three phases by the first author during the process of developing the article: 1) extracting data to a database with use of the generalized access model (Fig. 1); 2) developing country-specific flow charts which included all extracted data and 3) processing the data in the manuscript. During these phases, the first author checked the data by comparing the extracted data to the sourced publications during the various phases. The data was checked similarly by the second author during each phase. Moreover, the process was checked by four involved authors. Data included in the selected publications was sorted and categorized according to market access, patient access and/or effective patient access, and subsequently ordered by EU country. The full (country-specific) forms of the abbreviations mentioned in Results section are listed in Appendix B (Supplementary Material). The selection of EU countries, included and compared in the results of this study, was based on the availability of the data in the literature.

2.4. Validation and update

An update of the search was conducted from December 2015 until January 2018 to check for those publications within this time period that could be relevant for the study results.

The data was validated in August-September 2018. The validation took place with representatives involved in the reimbursement assessment (e.g. executive bodies) and/or reimbursement procedures (e.g. decision-making bodies) from each country (through telephone contact or e-mailing) with the aim to correlate and confirm our literature findings with current practice. For this purpose, we have contacted health technology assessment (HTA) agencies and governmental institutions through the network of the European Network for Health Technology Assessment (EUnetHTA) and the Dutch Ministry of Health, Welfare and Sport's; the EU Working Group on Medical Devices (via the Dutch National Health Care Institute (ZIN) and health policy advisor in Brussels) and authors of key publications included in this study.

3. Results

3.1. Publication selection

In total, 3806 citations were retrieved from MEDLINE/PubMed, Embase (Ovid) and Scopus covering the time period of January 2000 to December 2015. A total of 844 duplicate citations were identified and excluded. The 2962 unique publications then were screened on title and abstract. In total, 2722 publications were excluded based on title and abstract. The texts of the remaining 240 publications were assessed for eligibility. In total, this led to the exclusion of 200 publications. The rate of agreement between first and second author in both processes was 99%, which was considered as sufficient. Among the excluded publications were publications that did not meet inclusion criteria, mostly because the publications focused on the EU (without country-specific information; n = 60); the main objective was different from that of this study (n = 44) and the publications contained information on a specific device without addressing the main objective of this study (n = 41) (Fig. 2).

A total of 40 eligible publications were included in this study, consisting of: descriptive papers (n = 22), editorials (n = 2), posters (n = 2), correspondence papers (n = 1), literature reviews (n = 5), retrospective studies (n = 3), directories (n = 2), books, comments and specials reports (n = 1 each). Three articles were the result of meetings. Data from publications was organized on: market access (n = 9) [6,8,10,22–27], patient access (n = 17) [12,13,28–42], effective patient access (n = 0) or a combination (n = 14) [9,16,43–54]. Depending on the type of access, the included publications provided data about France, Germany, Italy, Spain, the United Kingdom (UK), the Netherlands, Sweden and/or Poland (see 3.2.1., 3.2.2. and 3.2.3. for the specification of reported countries by access type). Most of the publications were in English. However, publications in German (n = 5) [27,29,35,47,49] and Italian (n = 1) [33] were also included. Fig. 2 depicts the process of inclusion and exclusion of publications in this study using a PRISMA flow diagram [55].

Prior to the data extraction, the access model was developed (Fig. 1). This is a generalized model, of which key components we focused on in this study are displayed. The components were based on the online EU healthcare systems roadmaps [21], and verified during full text assessment. In this model, the pathway towards effective patient access is reflected comprising several procedures and practices. Market and patient access are two subsequent intermediary access levels included to display the finalization of the two main procedures: market approval procedures and reimbursement procedures respectively. After these procedures, realization of patient access (effective patient access) is achieved through certain practices defined as prescription by the physician and utilization by the patient.

Both market approval and reimbursement procedures consist of multiple (corresponding) components that are crucial in the process to access (e.g. evidence generation, application and assessment) leading to market approval or inclusion in a reimbursement scheme. Reimbursement procedures are separately described for the in- and outpatient sector. As a reimbursement scheme is subject to the type of healthcare system, the source of funding and the paying body, we also included these components in the study. Authorities that play a role in the assessment and decision-making procedures are incorporated in the model.

The content of this section comprises information on procedures and practices for effective patient access, structured in accordance with the three access processes shown in Fig. 1. For each of the eight EU member states, the available information is described in this Results section. The unavailability of information in included publications regarding the steps shown in Fig. 1 was not specifically mentioned for each country.

3.2. Data on market access, patient access and effective patient access

3.2.1. Market access

3.2.1.1. Market approval procedures. Market access to MDs was the main objective in nineteen publications, and concerned five countries: France (n = 3) [16,50,51], Germany (n = 4) [27,43,47,49], the UK (n = 11) [6,8,10,22–24,26,43,52–54], Sweden (n = 2) [48,53], and/or Poland (n = 1) [25].

Uniform market approval procedures were described for these EU member states. A device has to be certified by means of a CE mark before it can be placed on the market [6,8,52]. The assessment of MDs depends on the risk classification: class I (low risk), class IIa (low-moderate risk), class IIb (medium risk) and class III (high risk) (16, 23, 51, 52). Low-risk devices (class I) can be self-certified by the manufacturer on the basis of safety and performance. Class II and III devices' applications are supported by a literature review or clinical data that can either originate from the device itself or equivalent devices [8,22,23,27,47,49,52]. For class III devices, effec-

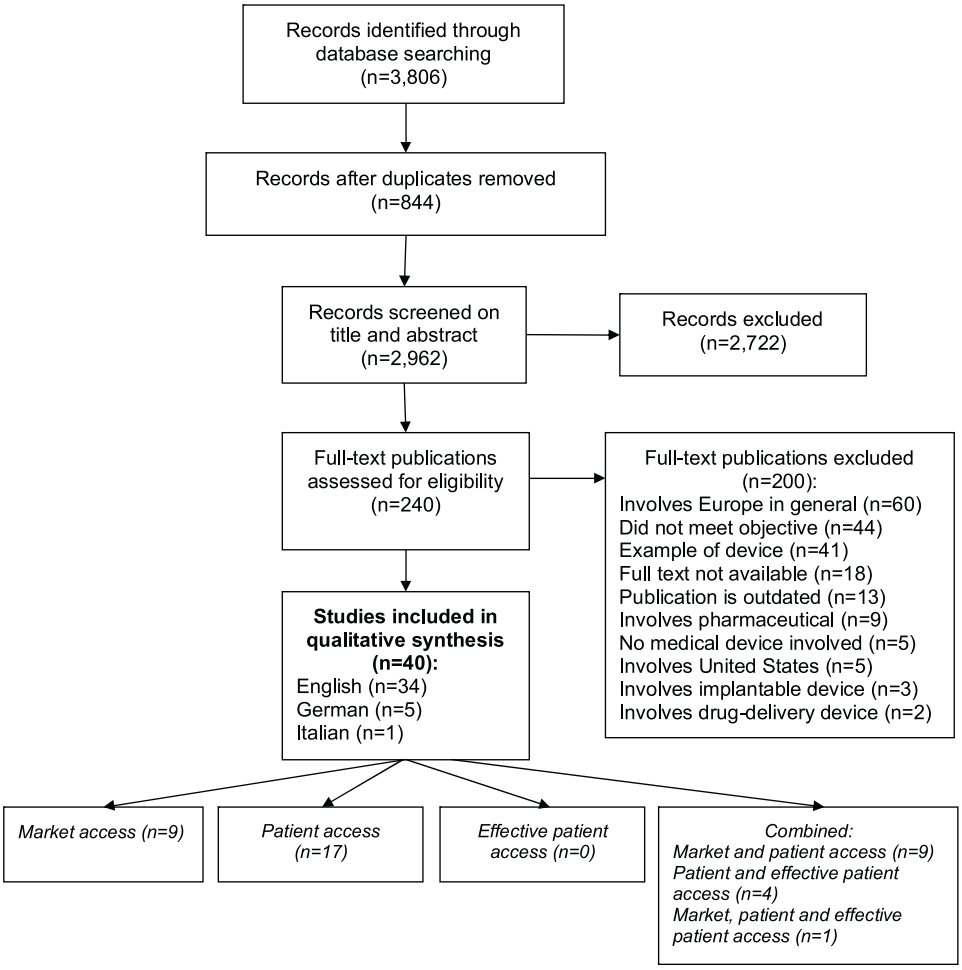

Fig. 2. Flow diagram of publication selection process.

tiveness data is required [51]. The assessment is carried out by independent organizations that are chosen and paid by the manufacturer, known as 'notified bodies'. There are approximately 80 notified bodies across the EU [6,16,26,43]. Notified bodies assess compliance with safety and performance requirements in the EU directives and, in the case of high risk devices, the effectiveness of the device [16,50,51]. The device is CE marked when considered eligible, which also implies market approval for all other EU member states [6,8,52]. In each EU member state, notified bodies are assigned and audited by a national competent authority. In addition, the competent authority regulates MDs by evaluation of vigilance data in the (post-)market approval phase, providing guidance for certain MDs and checking that manufacturers comply with regulations [8,16]. The national competent authorities of France, Germany, the UK and Sweden are the National Agency of Drug Safety and Health Products (ANSM) [50], the Federal Institute of Medicinal Products and Medical Devices (BfArM) [43], the Medicines and Healthcare products Regulatory Agency (MHRA) [10,52–54] and the Medical Products Agency (MPA), respectively [48].

In practice, some differences concerning market approval procedures can be observed due to decentralized implementation of the notified bodies, thereby leading to inconsistencies in applying the assessment procedure [8,26,52]. Whether differences in the implementation approaches of the competent authorities occurred was not described in the literature. Therefore, a statement on the generalizability could not be made. Also, in Poland, manufacturers may only use Polish during submission and labeling of devices [25].

3.2.2. Patient access

Twenty-seven publications specified reimbursement procedures in the EU member states. Extracted data from the included publications were related to seven countries. Most of the publications concerned France (n = 13) [9,13,16,31,34,38,39,41–43,46,50,51] and Germany (n = 17) [9,12,13,29,31,32,35–38,40–42,44,46,47,49]. In addition, some information was available for the UK (n = 11) [9,13,31,38,41–43,46,52–54], Italy, (n = 9) [9,13,28,30,33,41,42,45,46] Spain (n = 5) [13,28,41,42,45], Sweden (n = 2) [41,48] and/or the Netherlands (n = 2) [38,41] either on reimbursement procedures related to the inpatient and outpatient sectors and/or related to research programs. The most important findings that addressed the components included in Fig. 1 that were available in the literature for these countries are summarized in this section (see Appendix C (Supplementary Material) for an extended version). However, often detailed descriptions of application and assessment were not mentioned in the included publications, as can be seen in Table 2a. That table is an overview of results according to the reimbursement procedures defined in the generalized access model (Fig. 1), subdivided into inpatient sector and outpatient sectors (Tables 2a and b), payment system and healthcare system (Table 2c in Appendix D, Supplementary Material).

Table 2a
Extracted data from literature on reimbursement procedures in the inpatient sector in seven EU countries.

Country	Reimbursement scheme (described in literature)	Application criteria (reimbursement and pricing)	Assessment criteria (reimbursement and pricing)	Executive body	Decision-making body
France	1. DRG	1. -	1. -	1. -	1. -
	2. Additional payments (APM)	2. LPPR registration	2. -	2. -	2. -
	3. CED (RP)	3. LPPR registration[a]	3. -	3. -	3. -
	4. PHRC, PRME (RP)[b]	4. -	4. -	4. CNEDiMTS	4. Ministry of Health
Germany	1. DRG	1. -	1. -	1. -	1. -
	2a. DRG: New DRG group	2a. Information on: inappropriateness of existing DRG, new DRG, OPS and ICD coding and change on cost weight	2. -	2a. InEK	2a. InEK
	2b. DRG: New OPS code	2b. Information on: procedure, patients treated yearly, device distribution and change on cost weight	3. -	2b. DIMDI	2b. DIMDI
	3. Supplementary payments (APM)	3. -	4. -	3. -	3.-
	4. NUB (APM)	4. Information on: procedure, patients treated yearly, device distribution and change on cost weight, innovative aspects of device and overview available evidence	5. -	4. InEK	4. In EK. Pricing: negotiations hospital and SHI
	5. CED (RP)	5. Available evidence, proposal for clinical evaluation, information on potential device and costs		5. IQWiG	5. G-BA
UK	1. HRG	1. -	1. -	1. -	1. -
	2. Additional payments (APM)	2. -	2. -	2. -	2. Negotiations hospital and central or regional authorities
	3. CED (RP)	3. -	3. -	3. NICE	3. NICE
Italy	1. Per-case tariffs	1. -	1. -	1. -	1. Pricing: Reference pricing
	2. Additional payments (APM)	2. -	2. -	2. -	2. Negotiations hospital and central or regional authorities
Spain	1. Global hospital budget	1. -	1. -	1. -	1. Negotiations hospital and regional authority or third-party
	2. Additional payments (APM)	2. -	2. -	2. -	2. –
Netherlands	CED (RP)	–	–	–	Ministry of Health

This table is structured according to the reimbursement procedures in the inpatient sector of the generalized model (Fig. 1). Available reimbursement schemes are numbered per country.
Sources: Summary of available data derived from the publications in the reference list.
A dash (-) means not available in the literature.
Abbreviations: APM additional payment method; CED coverage with evidence development; CNEDiMTS National Committee for the Evaluation of Medical Devices and Health Technologies; DIMDI German Institute for Medical Documentation and Information; DRG diagnosis-related group; G-BA Federal Joint Committee; HRG Healthcare Resource Group; ICD International Classification of Diseases; InEK Institute for the Hospital Remuneration System; IQWiG Institute for Quality and Efficiency in Healthcare; LPPR list of products and services; NA not applicable; NHI National Health Insurance; NHS National Health Service; NICE National Institute for Health and Care; NUB new examination and treatment methods; OPS German procedure classification; PHRC Program for Hospital Clinical Research; PRME Program for Medical Economic Research; SHI Statutory Health Insurance; TLV Dental and Pharmaceutical Benefits agency; RP research program; UK United Kingdom.
[a] Applicable to non-implantable devices.
[b] PHRC and PRME do not provide national reimbursement; they are local in-hospital research programs.

3.2.2.1. Reimbursement procedures: inpatient and outpatient sectors. In France, devices used in the inpatient sector are reimbursed through diagnosis-related groups (DRGs) [9,16]. Additional payments apply to innovative and costly devices in the form of conditional reimbursement if the DRG system has not yet been updated [16,31,34,41]. In the outpatient sector, MD reimbursement occurs as a result of registration on the list of products and services qualifying for reimbursement (LPPR) under the 'generic line' (under existing categories) or 'brand name' (in case of innovative MDs). No assessment is necessary under the generic line. Registration under a brand name requires a literature search and clinical data in the French regime, what may originate from similar devices [16,31,34,39]. The application is assessed by the National Committee for the Evaluation of Medical Devices and Health Technologies (CNEDiMTS) in terms of expected benefit (EB), including benefit/risk ratio, role of the MD during treatment and public health impact. When the EB is found to be positive, the device is assessed on the expected added clinical value (EACV), comparing the device to the current gold standard for treatment [16,31,39,50,51]. The Economic Committee for Health Products (CEPS) negotiates the

Table 2b
Extracted data from literature on reimbursement procedures in the outpatient sector in seven EU countries.

Country	Reimbursement scheme (described in literature)	Application criteria (reimbursement and pricing)	Assessment criteria (reimbursement and pricing)	Executive body	Decision-making body
France	1a. LPPR: brand name	1a. Systematic literature search and clinical data	1a. EB and EACV	1a. CNEDiMTS	1a. Ministry of Health, Pricing: Negotiation CEPS and manufacturer
	1b. LPPR: generic line	1b. -	1b. NA	1b. NA	1b. NA
Germany	1. EBM	1. RCT or intervention study, and CEA or BIA	1. (Cost-)effectiveness	1. IQWiG	1. G-BA
	2. IGeL	2. Overview of available evidence and costs	2. Inclusion in GOÄ fee schedule	2. -	2. -
	3. TAS	3. See EBM application. No benefit: technical report	3. (Cost-)effectiveness[a]	3. IQWIG. No benefit:	3. G-BA. No benefit: GKV Spitzenband
	4. GOÄ	4. Overview of available evidence, device usage and costs	4. -	4. GMA	4. GMA
	5. CED (RP)	5. Overview of available evidence, proposal for clinical evaluation, information on potential device and costs	5. –	5. IQWiG	5. G-BA
UK	1. Drug tariff list	1. Clinical data	1. (Cost-)effectiveness	1. NICE and NHBSA	1. NICE and NHBSA
	2. CED (RP)	2. -	2. -	2. NICE	2. NICE
Italy	–	International and local data	–	–	–
Spain	–	International and local data	–	–	–
Netherlands	CED (RP)	–	–	–	Ministry of Health

This table is structured according to the reimbursement procedures in the outpatient sector of the generalized model (Fig. 1). Available reimbursement schemes are numbered per country.
Sources: Summary of available data derived from the publications in the reference list.
A dash (-) means not available in the literature.
Abbreviations: APM, additional payment method; BIA, budget impact analysis; CED, coverage with evidence development; EACV, expected added clinical value; EB, expected benefit; EBM, the Statutory Health Insurance Physician Fee Schedule; CEA, cost-effectiveness analysis; CEPS, Economic Committee for Health Products; CNEDiMTS, National Committee for the Evaluation of Medical Devices and Health Technologies; GKV-Spitzenband, National Association of Statutory Health Insurance Funds; GMA, German Medical Association; GOÄ, Private Health Insurance Physician Schedule; IGeL, Individual Health Services; IQWiG, Institute for Quality and Efficiency in Healthcare; LPPR, list of products and services; NA, not applicable; NHS, National Health Service; NHSBSA, National Health Service Business Service Authority; NICE, National Institute for Health and Care; TAS, Therapeutic Appliance Schedule; TLV, Dental and Pharmaceutical Benefits agency; RP, research program; UK, United Kingdom.
[a] In case of therapeutic effect.

price with the manufacturer, and that is subject to reference pricing. In case of a positive decision by the Ministry of Health, this results in LPPR registration and publication [9,13,34,39,42,46,50]. MDs are reimbursed by the National Health Insurance (NHI) that is funded mainly through employers' contributions and payroll deductions [9,16,34,39].

In the inpatient sector in Germany, adoption of a MD is permitted without proving benefit unless the MD is rejected based on available evidence [38]. Devices enter a DRG if there is a suitable DRG and German procedure classification (OPS). The Institute for the Hospital Remuneration System (InEK) and the German Institute for Medical Documentation and Information (DIMDI) decide on new DRG groupings and OPS coding respectively [12,32,37,47]. Reimbursement of devices used in inpatient care can also occur through supplementary payments from a hospital's budget [37,41]. Innovative and costly MDs can be reimbursed through the new examination and treatment methods (NUB), an extra-budgetary local payment, until the DRG system has been updated. Pricing of an NUB is negotiated between the hospital and the Statutory Health Insurance (SHI) [29,32,37,38,42]. Devices used in the outpatient clinic and ambulatory care are incorporated into Statutory Health Insurance Physician Fee Schedule (EBM) and Therapeutic Appliance Schedule (TAS) respectively. The MD is assessed on (cost-)effectiveness (for devices in TAS only in case of a therapeutic effect) and evaluated by the Institute for Quality and Efficiency in Healthcare (IQWiG), following which inclusion is decided by the Federal Joint Committee (G-BA) [12,13,29,32,38,40,47]. In addition, devices that are not eligible for EBM can be applied to an Individual Health Services (IGeL) scheme for self-paying patients [32]. TAS and EBM are reimbursed by the SHI through fee schedules funded by the contributions of employers and employees [9]. For patients who are insured by Private Health Insurance (PHI), other schemes exist. Devices used in the outpatient sector are included in the Private Health Insurance Physician Schedule (GOÄ) once agreed by the German Medical Association (GMA) [32]. Pricing of devices in the outpatient sector occurs through reference pricing or competition by means of public tendering [9]. MDs that are bought at a pharmacy are priced based on negotiations between the National Association of Statutory Health Insurance Funds and Federal Association of Pharmacists [35]. Additional payments must be made by patients if the costs of the preferred device are higher than the reference price [41,44].

The UK maintains the Healthcare Resource Group (HRG) system for the inpatient sector, and that is similar to the DRG system. Additional payments may be provided at a national level [9,41,42]. In the outpatient sector, MDs have to apply for inclusion on the drug tariff list [9,13]. The adoption of innovative or costly devices and devices with a high risk profile requires (cost-)effectiveness data [41]. The National Institute for Health and Care Excellence (NICE) assesses the application on indication and makes recommendations on reimbursement [43,52–54]. Pricing is set using mainly reference prices [41]. Devices are reimbursed by the National Health Service (NHS) through central taxes, and organized by decentralized Clinical Commissioning Groups (CCGs) [13,46].

In Italy, reimbursement of MDs is stipulated at a national level by the Ministry of Health and the Medical Device Committee (CUD) [13,33,42]. However, actual access to MDs is arranged separately in 20 Italian regions [9,42,45]. The inpatient sector is regionally funded by per-case tariffs [9,30,42,45]. Additional local payments may be accessible in negotiation with central or regional authorities. Pricing of certain devices (e.g. knee prosthesis and coronary stents) is decided nationally using reference prices [41,42,45]. Devices used in the outpatient sector are assessed per region and require both international data and data collection in the respective region. Funding is provided by the NHS derived from central and regional taxes. MDs are covered in the 'essential levels of care' (LEA). However, the LEA does not explicitly define the care that is reimbursed, leading to heterogeneous provision of care regionally [28,30,33,45,46].

Spain also has a decentralized system at the level of the autonomous communities (ACs). The inpatient sector is paid out of a hospital's budget [13,41,45]. Reimbursement of MDs depends on the contract program that is agreed between the hospital and regional authorities or other payers [45]. Additional payments have been reported in Spain [41]. Pricing is determined by a fixed profit margin [42]. The procedure concerning the outpatient sector was described as being similar to that in Italy [13]. Taxes and national budgets are the main funding sources [45].

Sweden consists of 21 regions with 290 municipalities. Dahlberg et al. [48] describes a decentralized system for assistive devices. Regions and municipalities organize device provision. Decisions on reimbursement are made by an independent governmental organization: the Dental and Pharmaceutical Benefits agency (TLV). Reimbursement is assured through tax income [48,53].

3.2.2.2. Reimbursement procedures related to research programs. Various research programs are mentioned for France (see below). The coverage with evidence development (CED) program was described in two articles and has been implemented in France, Germany, the UK and the Netherlands. CED provides conditional reimbursement to innovative devices and simultaneously fosters evidence collection to prove the (cost-)effectiveness of the device [31,38].

CED in France provides reimbursement over at least two years. The CNEDiMTS selects suitable candidates for the program and assesses the application. The Ministry of Health decides which MD will enter the CED program funded by the NHI. Apart from CED, two local research programs are available: the Program for Hospital Clinical Research (PHRC) and the Program for Medical Economic Research (PRME). PHRC and PRME programs are in-hospital programs for which the research departments of hospitals can tender. An independent expert team assesses each application dossier and decides with regard to the PHRC, used for fundamental research, and PRME, used for economic evaluation [31,34,38].

The dossier for applying to CED in Germany can be filed by manufacturers, impartial members or patient representatives of the G-BA, the regional and federal associations of SHI physicians and the federal association of SHI funds. The IQWiG is responsible for evaluating that the application conforms to the criteria mentioned in Olberg et al. [38]: validity, plausibility and applicability. Subsequently, the G-BA makes the final decision on incorporation in the CED. Such a program is funded jointly by the SHI and manufacturer [31,32,38].

In the UK, application for CED is assessed by NICE. The CED program is offered in different forms: use of the MD in clinical practice with additional evidence collection ('Approval With Research' (AWR)) or only for research purposes ('Only In Research' (OIR)). CED is reimbursed by various stakeholders, including the NHS and manufacturers [31,38].

In the Netherlands, the Ministry of Health selects MDs that are eligible for CED. Data on (cost-)effectiveness of the MD is gathered throughout the program. Each clinical study is funded by the Netherlands Organization for Health Research and Development and other payers (e.g. manufacturers) [38,41].

3.2.3. Effective patient access

Following reimbursement, both the physician (as the prescriber) and the patient (as the user) play a role in the final step of gaining effective access to MDs. Five publications described such practices in six countries: France (n = 1) [46], Germany (n = 2) [44,46], the UK (n = 1) [46], Italy (n = 3) [9,45,46], Spain (n = 1) [45] and/or Sweden (n = 1) [48]. Information given about the practices in the included publications varied among device types. Therefore, various device types are explicitly described in this section.

3.2.3.1. Practices: physician as the prescriber. Stoma devices (used after ileostomy, colostomy or urostomy) in France and Germany are provided after prescription of the device by the specialist or the general practitioner (GP). The physicians can choose which brand they want to prescribe.

In Germany, the patient is provided with the stoma device after leaving the hospital. Additional supplementation is prescribed by the GP [46]. Some assistive MDs that are not registered in the TAS are allowed to be prescribed by the physician once the need has been established [44].

Stoma devices are initially prescribed by the specialist in the UK and continued by the GP. To avoid brand selection by specialists, the NHS motivates hospitals to collaborate with suppliers of stoma devices in return for covering the costs at the unit [46].

In Italy, after reimbursement, provision of knee prostheses and coronary stents can be dependent on the costs of such devices. When various types of knee prostheses are reimbursed in the same DRG, the physicians from private institutions tend to offer patients the less costly devices [9,45]. However, this does not apply to various types of implantable cardioverter defibrillators. Decision-making regarding effective patient access to coronary stents is also reported to be dependent on the relationship between hospital managers and physicians [45].

Long waiting times for surgical treatment were described for Spain when that involves the provision of knee prostheses. The educational level and medical cultures of physicians have been associated with variation between the implantable cardioverter defibrillators provided in various regions [45].

In Sweden, access to assistive devices is usually enabled through prescription by healthcare providers. However, in some regions, provision of assistive devices is achieved by applying a voucher system. In the process of the voucher system, the patient receives a voucher from the prescriber. With the voucher, patients can choose the device that is preferred. The assistive device is fully paid for by the patient if the device is not funded publically [48].

3.2.3.2. Practices: patient as the user. Patients can fulfill a prominent role in the brand selection of a device in case a voucher system is used. In Sweden, this system enables patients to participate in choosing the most suitable assistive device, and spend the voucher on a brand and type of device that is preferred [48].

There is a trend of direct sponsorship of oncology units in the UK by MD suppliers, giving them preferred supplier status. This limits the physicians' ability to prescribe brands other than those from the sponsoring suppliers [46].

In Germany, the patient can select an assistive device that is preferred, but then has to pay additional costs if they exceed the costs of the device recommended by the health insurer [44].

3.3. Barriers and facilitators related to early effective patient access

An overview of the barriers to and facilitators of early effective patient access is presented in this section. The factors were extracted from 23 publications and covered Poland (n = 1) [25], France (n = 6) [16,31,34,38,39,41], Germany (n = 8) [12,28,29,36–38,41,49], Italy (n = 6) [9,13,28,30,41,45], Spain (n = 5) [13,28,30,41,45], the UK (n = 5) [28,38,41,52,54], Sweden (n = 2) [41,48], the Netherlands (n = 1) [38] and/or EU in general (n = 8) [6,16,28,31,43,51,52]. Factors were analyzed as barriers and/or facilitators, and enumerated in Table 3.

3.3.1. Barriers and facilitators: market access

In Poland, manufacturers must document and communicate in Polish, which was the only country-specific factor at the level of market access [25]. In the current analysis, we considered this as a barrier for international manufacturers to obtain early effective patient access.

Barriers that apply to EU member states in general were: unclear EU legislation regarding the requirements for pre-marketing study designs, difficulty in understanding the market approval procedures and demotivation of manufacturers in performing long-term studies due to complex study designs, the tendency to require a higher level of evidence under the new regulations compared to the MD directives, difficulty of keeping track of MD use by physicians and the typically short lifecycles of innovative MDs [6,16,31,51].

Data on effectiveness of the device is not always required for market approval in the EU, thereby facilitating time to market access up to three years earlier in comparison to the US [6]. Also, the application for market approval may be supported by data from similar existing devices [52].

3.3.2. Barriers and facilitators: patient access

Barriers to and facilitators of evidence requirements during reimbursement procedures concerned France, Italy and Germany. In France, a lack of focus on public health benefit and high quality studies are factors that are considered to influence the EB negatively [39]. Devices that meet the technical standards are supported with recommendations and guidelines, and if accompanied by information on similar preceding MDs are more likely to obtain a positive vote on the EB by CNEDiMTS and therefore facilitate early effective patient access. Evidence comprising nonspecific clinical data and is available early in the development prevents that patient access to (innovative) MDs with short lifecycles being impeded [16,39]. For evidence collection in France and Italy, data specific to their country facilitates the reimbursement assessment. However, this can also be a barrier to early effective patient access because, instead of using existing data derived from other countries, the data has to be gathered explicitly in the respective country which can be time-consuming [13,34]. In Germany, the barriers mentioned in the literature constituted of the need for blinding and randomization in clinical trials, a lack of evidence collection during clinical trials due to cost pressures and lack of personnel in the clinic, and the evaluation of cost-effectiveness by IQWiG and G-BA [29,36,49]. In addition, conducting clinical trials is both costly and time-consuming for small German companies, which may prevent innovative MDs from entering clinical practice. Therefore, networks between manufacturers — that have been initiated to provide an infrastructure to support multicenter trials - facilitate early effective patient access [49].

Organizational barriers and facilitators were reported to be related to the healthcare system and reimbursement procedures in Germany, the UK, Italy and Spain. In Italy and Spain, reducing public healthcare provision, austerity, a decrease in healthcare spending and budgetary cuts have a negative influence on early effective patient access [28]. Also, the regional arrangement of MD provision in Italy, Spain and Sweden can be difficult for the manufacturers when wanting to disseminate their MD at the national level [13,45,48]. Unlike the global hospital's budget in Spain, DRG-based systems implemented, for example, in Italy, the UK and Germany, help serve adoption of innovative MDs in hospitals [28,30]. Concerning the reimbursement procedures, it was stated that the application of the German HTA is delayed by the decentralization of bodies involved in the HTA assessment, and therefore impede progress towards patient access [12]. Guidance programs for MDs provided by NICE in the UK have a positive influence on the reimbursement by the NHS [52,54].

Financially driven barriers were found to be difficulties with funding of MDs in France and Germany. In the case of Germany, the NUB is only provided when hospitals negotiate with SHI [12,16,37]. Additional payments systems (in France, Germany, Italy, the UK, Spain and Sweden) and funded research programs (in France, Germany, the UK and the Netherlands) facilitate early adoption of MDs in the inpatient clinic [38,41].

No facilitators were mentioned at an EU level. Non-transparency with regard to the reimbursement procedures, requirements for country-specific data and inapplicability of performing randomized controlled trials (RCTs) during MD evaluation constitute general barriers in EU member states [28,43,51].

3.3.3. Barriers and facilitators: effective patient access

The physician is exposed to various device-specific barriers and facilitators that determine how and if the MD is prescribed to the patient. Costs of the device types, waiting times and hospital-physician relationships have been analyzed as factors influencing early effective patient access [9,45]. The patient as a user of MDs was not reported to affect early effective patient access.

3.4. Results of validation and update

The update search revealed 656 further publications, and screened on title and abstract. The remaining publications were screened on full text and checked for eligibility (n = 31). No conclusion-changing publications were found. Publications that were found to be relevant, e.g. regarding the implementation and content of the MDR throughout the EU, are discussed in the Discussion section. In addition, barriers to and facilitators of early effective patient access related to the MDR can only be evaluated in literature after the MDR has been implemented for a longer period of time.

To ensure the accuracy of the data included in this study, we recruited representatives from each country for validation. In total, six out of eight countries responded. In addition, in this study, little evidence regarding the practices related to MD use in Denmark was reported to be inconsistent with current practice by the Danish representative from the National Board of Social Services. This information was therefore excluded from this study. For the included countries, we were able to validate core findings with representatives of Germany, the Netherlands, France, Poland, Sweden and the UK. The representatives are employed at the National Association of Statutory Health Insurance Funds (GKV-Spitzenband), ZIN, French National Authority for Health (HAS), Agency for Health Technology Assessment and Tariff System (AOTMiT) and TLV. The UK was represented by an author of one of the key publications included in the review. All representatives confirmed key findings to reflect current practice. The German representative noted additionally that in practice, the G-BA does not decide about the costs of MDs. The G-BA may assess cost-effectiveness, but usually focusses on patient-relevant medical benefits and damage potential of the device. This is due to the fact that usually there is too little evidence on the effectiveness between two methods, whereby

Table 3
Barriers and facilitators to early effective patient access.

Country	Study	Access	Barriers	Facilitators
Poland	Bondaryk 2008 [20]	MA	• Documentation and communication in Polish language	
France	Gilard et al. 2013 [29]	PA	• Data for application PA is specific to French setting[a]	• Data for application PA is specific to French setting[a]
	Guillou 2011 [42]	PA	• Difficult access to funding	• Available evidence early in device development
	Loge et al. 2015 [34]	PA	• Lack of focus on public health benefit	• Device measures up with technical standards
			• Lack of high quality studies	• Device is accompanied by information on preceding devices
				• Device is supported by recommendations and guidelines
				• Application PA is supported by existing evidence from similar devices
	Martelli et al. 2014 [26]	PA		• PHRC and PRME
	Olberg et al. 2014 [33]	PA		• CED
	Sorenson et al. 2013 [36]	PA		• Additional payment systems
Germany	Heinemann 2014 [31]	PA	• Evaluation on cost-effectiveness by IQWiG and G-BA	
	Henschke et al. 2010 [32]	PA	• NUB only available locally	• NUB
	Hertz et al. 2012 [23]	PA		• DRG-based system
	Hessel 2005 [11]	PA	• Difficult access to funding • Decentralization of bodies involved in HTA assessment	
	Olberg et al. 2014 [33]	PA		• CED
	Seidel et al. 2014 [45]	PA	• Evidence collection is not well implemented in practice •Conduction of trials is costly and time-consuming for small manufacturers	• Networks between manufacturers
	Sorenson et al. 2013 [36]	PA		• Additional payment systems
	Zens et al. 2015 [24]	PA	• Blinding in trials is not feasible and placebo-controlled studies are seen as unethical	
Italy	Cappellaro et al. 2009 [40]	PA/	• Regional organization of device provision	• Relational in-hospital affairs[a]
		EPA	•Relational in-hospital affairs[a]	
				• Relational in-hospital affairs[a]
	Cappellaro et al. 2009 [40], Schreyogg et al. 2009 [7]	EPA	• Amount of costs of device type	
	Finocchiaro Castro et al. 2014 [25]	PA		• DRG-based system
	Hertz et al. 2012 [23]	PA	• Less provision of healthcare, austerity, decrease in healthcare spending and reduction measures	
	Schafer et al. 2013 [12]	PA	• Data for application PA is specific to Italian setting[a] • Diverse requirements for application PA among regions	• Data for application PA is specific to Italian setting[a] • Reimbursement approval in prominent regions
	Sorenson et al. 2013 [36]	PA		• Additional payment systems
Spain	Cappellaro et al. 2009 [40]	PA/EPA	• Regional organization of device provision • Waiting times for surgical treatment	
	Hertz et al. 2012 [23]	PA	• Less provision of healthcare, austerity, decrease in healthcare spending and reduction measures	
	Finocchiaro Castro et al. 2014 [25], Hertz et al. 2012 [23]	PA	• Global hospital budget	
	Schafer et al. 2013 [12]	PA	• Diverse requirements for application PA among regions	• Reimbursement approval in prominent regions
	Sorenson et al. 2013 [36]	PA		• Additional payment systems
UK	Campbell 2013 [48], Dobbs 2007 [50]	PA		• Guidance programs by NICE
	Hertz et al. 2012 [23]	PA		• DRG-based system
	Olberg et al. 2014 [33]	PA		• CED
	Sorenson et al. 2013 [36]	PA		• Additional payment systems

Table 3 (*Continued*)

Country	Study	Access	Barriers	Facilitators
Sweden	Dahlberg et al. 2014 [44]	PA	• Regional organization of device provision	
	Sorenson et al. 2013 [36]	PA		• Additional payment systems
Netherlands	Olberg et al. 2014 [33]	PA		• CED
EU	Guillou 2011 [42]	MA	• Complex MA procedures	
	Boudard et al. 2013 [47], Cohen 2013 [5]	MA	• Requirement of higher level of evidence	
	Cohen 2013 [5]	MA		• Application MA requires less clinical evidence in EU compared to US
	Campbell 2013 [48]	MA		• Application MA is supported by existing evidence from similar devices
	Martelli et al. 2014 [26]	MA	• Unclear EU legislation • Demotivation of manufacturers to perform long-term studies	
	Altenstetter 2003 [38]	PA	• Non-transparency in reimbursement procedures	
	Boudard et al. 2013 [47]	PA	• Inapplicability to perform RCTs	
	Hertz et al. 2012 [23]	PA	• Country-specific data for application PA	

Abbreviations: CED, Coverage with Evidence Development; EPA, Effective Patient Access; EU, European Union; IQWiG, German Institute for Quality and Efficiency in Healthcare; G-BA, Federal Joint Committee; HTA, Health Technology Assessment; MA, Market Access; NICE, National Institute for Health and Care Excellence; NUB, new examination and treatment methods; PA; Patient access; PHRC, Program for Hospital Clinical Research; PRME, Program for Medical Economic Research; RCT, Randomized Controlled Trial; UK, United Kingdom; US, United States.

[a] Factor is both a barrier and facilitator.

cost-effectiveness is difficult to assess. The Dutch representative noted that the consequences of the current MDR implementation will not be fully detectable in literature yet but will have an effect on market approval procedures in the coming years. The representative of the French HAS commented that in France, PHRC and PRME are not national reimbursement schemes, but rather local (in-hospital) research programs. The MDs used in the programs are not always funded publically; costly MDs are paid by the manufacturer. In Sweden, the regulation of reimbursement by TLV is limited to the devices needed to administer or monitor pharmaceuticals and stoma products [56]. In some cases, TLV assists with conduction of HTA of MDs [57]. Concluding, the validation confirmed our findings reported in the Results section 3.2.

4. Discussion

To our knowledge, this is the first systematic review to provide a comprehensive literature overview that takes into account country-specific market approval and reimbursement procedures and practices related to effective patient access to MDs in eight EU member states.

Information on the pathway towards market access mentioned for France, Germany, the UK, Sweden and Poland was uniformly described at an EU level [6,8,10,16,22–27,43,47–54]. Differences in implementation of the notified bodies were observed; however, differences could not be retrieved from the literature about the competent authorities [8,16,50,51]. Reimbursement procedures varied among the EU member states that were included in the current study. Our results suggest that reimbursement procedures are not only heterogeneous but also more complex and extensive when compared to market approval procedures [9,12,13,16,31,32,34,37,39,41,42,46,47,50,51]. Also, obtaining reimbursement in one country will not apply to other EU member states, as is the case with the CE mark [6,8,52]. Although we did not measure this aspect quantitatively, this reveals a negative influence over time to effective patient access throughout the EU, often resulting in a longer time needed for reimbursement than for market approval. Our findings are in line with previously published publications showing wide variations in reimbursement procedures across EU member states and a much longer time to obtain patient access compared to obtaining market access [4,17,58]. Basu et al. [4] measured the time differences between market and patient access, and described a one to three month duration for market approval procedures, whereas the time for reimbursement procedures ranged from 16.4 to 71.3 months.

One important aspect of MD approval that emerged from our study concerns the collection and assessment of evidence accompanying the MD. We observed notable differences in the evidence required for each phase. For market approval, safety and performance measures are assessed. In addition to these requirements, evidence for reimbursement approval often requires effectiveness data, data on post-market surveillance and a (cost-)effectiveness analysis [4,16,34,41,51]. The available evidence in the literature describes the disintegration of the market approval and reimbursement procedures. Consequently, evidence collection for e.g. cost-effectiveness analysis for reimbursement purposes can be hindered due to absence of evidence generation during the market approval phase [17,59,60]. Implementation of the new Medical Device Regulation (MDR 2017/745) will lead to stricter clinical evidence requirements and pre- and post-market control. The new MDR also contains changes to improve regulation, including stricter criteria that apply to notified bodies, improved transparency by developing an EU-wide MD database and providing traceability of MDs using a Unique Device Identification system [11,38,61].

The information on the prescription and utilization practices was scarce, especially when utilization of MDs by the patient is considered [44,46,48]. Available information concerning the patient's role in MD access showed no correlation with early effective patient access but focused mainly on brand selection by patients. Practices and factors affecting the time to patient access (e.g. costs of device types, waiting times and hospital-physician relationships) varied among specific device types [9,45]. According to Davis et al. [62], decisions regarding prescription of MDs by physicians are affected by the physician's perceived ease of use and usefulness of the device. Determinants that influence the ease of use and usefulness are: individual differences among physicians, device characteristics, social influence and facilitating conditions [63]. In this study, multiple factors, such as financial interests, organizational factors related to the work capacity and hospital managements, as studied by Cappellaro et al., were identified [45]. Our study indicates that

these are important examples of facilitating conditions. In addition, a further examination of the other determinants may also be valuable.

Barriers to and facilitators of effective patient access identified in this literature study correspond to the recently published study by Fuchs et al. [64], which explored the MD assessment by HTA institutions including challenges and future perspectives through semi-structured interviews with representatives of EU HTA institutions. Findings mentioned in this study related to the insufficient level of evidence collection and weak market access regulation were challenges reported in their study. In addition, adoption of CED, sufficient evidence collection and solving disintegration between the licensing and reimbursement process are key aspects in our study that were highlighted and concluded accordingly in their study.

4.1. Strengths and limitations

The main strength of this study is the systematic approach applied to obtain the data on patient access to medical devices in eight EU member states. Presenting the market approval and reimbursement procedures (inpatient and outpatient sectors) and practices according to the generalized access model shown in Fig. 1 strengthened the structure of this review. However, we acknowledge that country-specific aspects or details can differ among EU countries, so that this is rather a generalizable model on MD access. The results were described in a transparent manner, especially the section on reimbursement procedures, which is unique when compared to the findings reported in the available literature. In addition, all types of publications - including domestic publications - were taken into account to provide insight into the available evidence and access to the data written in languages other than English. The broad search strategy conducted in the three databases aimed to retrieve most important available evidence in the literature on the processes towards effective patient access and on barriers and facilitators. The update of the search and data validation provided reliable results in accordance with practice.

Several limitations to the study need to be taken into account. First, information on reimbursement procedures was only available for France and Germany due to the limited number of valuable health policy publications that had detailed descriptions of the processes towards effective patient access [16,31,32,39]. For the UK, Spain, Italy, Netherlands and Sweden, available information was scarce. Second, we are aware that by confining ourselves to the literature as the main source in this study, possibly valuable information regarding the eight countries discussed in this study was overlooked, but also regarding other EU member states. Third, although contacting authors of the eligible publications to confirm whether the data reflected current practice was a strength in this study, it was only effective in a small part, due to the low response rate. Fourth, an important limitation was the absence of information on quantifying time to access. Such information on time to access (data not shown) that was available was scarce and showed inexplicable discrepancies between publications regarding the length of reimbursement procedures, making it difficult to compare [13,16,34,40,42]. Fifth, changes may have occurred in the respective countries since the final update of the search and validation of the data. A restriction of the study is that we focused on all MDs irrespective of the risk class and use (inpatient or outpatient care) but excluded drug delivery devices, in vitro diagnostics and implantable powered electronic devices. Finally, a formal quality assessment was not performed in view of the nature of the publications, most of which contained level 4 evidence according to the hierarchy by Cochrane Collaboration; almost all was descriptive or policy oriented [65]. Therefore, we limited the data extraction to factual information.

4.2. Policy and research implications

From the findings of the current study, health policy suggestions were formulated. Time dependence on heterogeneous and extensive reimbursement procedures could be improved by simplifying and harmonizing these procedures across EU member states. This could also lower the costs of such procedures [66].

Collecting robust evidence prior to market approval that is obligatory for reimbursement of MDs could be established by better aligning the market approval and reimbursement procedures [59]. This recommendation also came out of a recent study that interviewed representatives from 16 EU HTA institutions [64]. The MDR may potentially help in solving this dilemma by its stricter evidence requirements [11].

Barriers created by unclear EU legislation [51] and complex market approval procedures [16] could be minimized by providing more feasible guidelines, in terms of uniformity, clarity and complexity, and that are more accessible to manufacturers by involved parties, such as the national competent authorities, incorporated in guidelines of EUnetHTA or the Global Harmonization Task Force worldwide [67]. Most countries have implemented a DRG-based system in the inpatient sector, thereby facilitating more effective patient access. By applying this system, costs and incomes are controlled within hospital departments, making healthcare providers more conscious of the healthcare spending and promoting the national provision of MDs. In countries such as Italy and Spain, costs are managed using tariffs and global budgets respectively, and provision is arranged at a regional level [13,45]. In these countries, effective implementation of DRG-systems (in Spain) and centralization of procedures would encourage reimbursement and provision of MDs nationally. But for now, it is both desirable and feasible for manufacturers to obtain approval in the more prominent, large scaled and influential regions in these countries, such that other regions will follow positive advice by means of the 'domino effect' [13].

Securing financing nationally for innovative and costly devices is crucial for MD adoption, especially in an early stage of device development. National implementation of funded research programs such as CED and additional payment systems as part of the reimbursement procedures should be prioritized by health policy makers across the EU to encourage the adoption of innovative MDs [31,37,38,41,66].

This current study provides an incentive to fill in the gap in the literature by consulting other sources, such as governmental reports, websites of health authorities and white papers. In addition, methodological alternatives such as time series analysis, review of case notes, surveys and interviews with health policy makers, members of relevant institutes and manufacturers could validate and generate in-depth information on barriers and facilitators [68]. In addition, involving researchers in the field in a survey study could have led to a broader perspective on this topic.

Further research should focus more on exploring the utilization of MDs by patients and prescription practices, taking into account both physician's individual and device characteristics of different device types [63]. This could be achieved by means of studies on specific devices involving conduction of surveys and interviews with healthcare professionals. We will further examine this in a future qualitative study focusing particularly on devices used in head and neck cancer rehabilitation.

More objective information should be provided on the taken time to achieve effective patient access. It should be taken into account that currently there are only four notified bodies (instead of 80) [69,70] due to the MDR which aims at a more centralized system with stricter requirements including the accreditation of notified bodies. Quantitative information on the time to access could be improved in the future by clearly describing the proce-

dures involved in measuring the time to access and defining criteria on (standard) measurement points in future studies [71]. In this way, time to access could be compared objectively among EU member states objectively. Furthermore, attention should be paid to differences in time to market access following the implementation of a new MDR, involving the provision of adequate evidence to protect the safety of patients without extending the time taken to make potentially beneficial devices available to patients [11].

5. Conclusions

In the literature, market approval procedures were uniformly described for the EU member states. Information on reimbursement procedures, with exception of France and Germany, and prescription practices was incomplete. Reimbursement procedures were heterogeneous across the EU, which had a significant impact on accessibility of MDs for patients. Little information was available about patients as users of MDs, and prescriptions by physicians varied among device types.

Important barriers to early effective patient access were found unclear EU legislation, complex market approval procedures, requirements for a particular level of evidence and evidence collection during reimbursement procedures, and reimbursement and provision of MDs at the regional level. Procedures concerning market and patient access are facilitated by sufficient evidence collection, implementation of a DRG-based system, additional payment methods and research programs. The physician's prescription was influenced by the waiting times, costs of device types and hospital-physician relationships, whereas none of the publications described the patient's role in early effective patient access.

Policy recommendations arising from this study include those for feasible guidelines on market access, alignment between market approval and reimbursement procedures, centralization of reimbursement procedures, additional payment methods and funded research programs. Furthermore, sourcing other information about reimbursement procedures and practices - including clearly defined measurement points regarding time to MD access - is highly recommended.

Conflict of interest

ATOS Medical AB had no involvement in the conduction of the study.

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Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.healthpol.2019.10.002.

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