A Scoping Review of Different Methods of Assessing the Impact of New Medical Technologies at Early Stages of Development

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Nader Tavakoli5

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Abstract

**Background:** Investing in the R&D sector of new medical technologies is associated with the risk of being rejected by paying organizations because of the lack of value-for-money. The purpose of this study is to investigate the different methods of evaluating the impacts of emerging medical technologies.

**Methods:** Using scoping review method, we analyzed studies that investigated methods for assessing the impacts of emerging medical technologies on development. To find these studies, the Cochrane Library, ISI Web of Knowledge, Embase, Ebsco and Pubmed databases from 2000 to 2018 were searched. The methodological quality of the studies was assessed using the STROBE Checklist. Two reviewers independently selected the qualified studies. Charting and collating the data were used based on the method proposed by Arksey and O’Malley.

**Results:** Overall, 38 studies met the inclusion criteria. Sixteen methods were identified and put in five distinct categories: forecasting, Pro-HTA, Early-HTA, priority setting, and HHS were found to measure the impact of emerging technologies. The quality of these studies was acceptable. Few studies were conducted on emerging pharmaceutical technologies, and they were mostly on emerging medical devices. The Early HTA methods were often used to measure the effects of pharmaceutical technologies and medical devices technologies. The Pro-HTA method used dynamic modeling to examine the impact of medical technologies on a broad range of dimensions, while the HTA and Early-HTA methods used cost-effectiveness techniques throughout the development process. The HHS method used a multivariate decision-making technique.

**Conclusion:** Different methods were used to investigate the impacts of emerging medical technologies. Chronologically Pro-HTA methods are new ways for investigating emerging medical technologies beyond clinical and economic impacts. Assessing the feasibility of implementing Pro-HTA in real environments deserves further research.

Keywords: Early Stages of Technology Development, New Medical Technologies, Health Technology Assessment, Emerging Pharmaceuticals

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Introduction

Medical Technological advances threaten financial sustainability in many health care systems; thus the efficient

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5. Trauma and Injury Research Center, Iran University of Medical Sciences, Tehran, Iran

†What is “already known” in this topic:
Classical Health Technology Assessment (HTA) is commonly used in the evaluation of medical technologies with sufficient available evidence. But some approaches are increasingly being used to support health economic evidence development during the early stages of technology development.

→What this article adds:
Sixteen methods were identified that investigated the impacts of emerging medical technologies. Chronologically Pro-HTA is a new method using a dynamic simulation approach for investigating emerging medical technologies beyond clinical and economic impacts. Assessing the feasibility of implementing Pro-HTA in real environments deserves further research.
and optimal allocation of resources are important challenges for the system (1). One of the ways to manage the consequence of technological pressure involves the presence of a health care system in charge of emerging technologies as soon as possible before the product is fully developed. The health care system would track emerging technologies and try to invest in products that are potentially cost-effective in addition to their significant clinical benefit (2).

Emerging medical technologies are always accompanied by uncertainty. On the one hand, the emergence of medical technologies leads to the expansion of national wealth, increased competitiveness, increased exports, and increased welfare and quality of life. On the other hand, it can lead to problems such as increased induced demand, increased medical costs without necessary efficacy, increased patients’ life span with poor quality of life (3, 4). So it is important to assess the clinical and economic consequences of emerging technologies. Common approaches, such as health technology assessment (HTA) reports, have not helped policymakers much in selecting and evaluating technologies (5).

Over the past two decades, the use of product assessment models in their early stages of development has been of interest to provide timely information for the ongoing process of development, market access, and technology pricing. The primary purpose of this study was to undertake a comprehensive review of the literature in the early stages of development to identify methods of a technology evaluation. The second purpose is to identify new methods to assess the potential impact of emerging medical technologies.

**Methods**

**Study Design**

This scoping review was conducted to identify different methods of evaluating emerging medical technologies in their early stages of development. We followed the methodology proposed by Arksey and O'Malley in five steps (6).

**Stage 1. Research question and eligibility criteria**

The research question concerns the current methods to evaluate potential impacts of new medical technologies in terms of clinical and economic consequences in the early stage of development to make a better decision regarding the governance of these technologies?

Inclusion criteria were all studies evaluating medical technologies at various stages of development before entering the market, such as seminal research, laboratory phase, animal phase, clinical phase, and pre-market launch. Medical technologies include those emerging health technologies used directly to diagnose or treat a health condition, e.g., medicines, medical devices, diagnostic tests or medical equipment.

**Stage 2. Identifying relevant studies**

The studies included a broad category of study designs to capture comprehensiveness. We included surveys, cross-sectional, descriptive, qualitative, national, and international reports, systematic reviews, and discussion studies. PubMed, Cochrane Library (through own website), ISI Web of knowledge, and Embase (through the Ovid website) from 2000 to 2018 were electronically searched to find potential eligible studies. We also tracked references of marker studies, the website of related organizations and conferences to find more relevant studies. Moreover, the studies presented in International Society for Pharmaceutical and Outcome Research (ISPOR) conferences (up to 2018) were also searched.

According to the study question and having reviewed the studies, the search strategies were written according to the guidelines of each database. Details for search strategies in two databases and retrieved records are available in an Appendix. The basic search strategies are as follows:

1. Model (Title/Abstract) OR tool (Title/Abstract) OR Simulation (Title/Abstract) OR forecast (Title/Abstract) OR foresight (Title/Abstract) OR future forecast process (Title/Abstract) OR technology foresight (Title/Abstract) OR health technology assessment (Title/Abstract) OR horizon scanning (Title/Abstract) OR prospective simulation (Title/Abstract) OR Pro HTA (Title/Abstract) OR dynamic model (Title/Abstract) OR prospective assessment (Title/Abstract)

2. Pharmaceutical innovation (Title/Abstract) OR Pharmaceutical diffusion (Title/Abstract) OR health technology diffusion (Title/Abstract) OR Emerging innovation (Title/Abstract) OR emerging drug (Title/Abstract) OR new drug (Title/Abstract) OR new medicine (Title/Abstract) OR drug entity (Title/Abstract) OR medicine entity (Title/Abstract) OR emerging health technology (Title/Abstract) OR healthcare innovation (Title/Abstract) OR medical device (Title/Abstract)

3. #1 AND #2

**Stage 3. Study selection**

We followed the PRISMA guidelines to find relevant studies. We included studies with methods to assess the impacts of emerging technologies on the health care system, such as new pharmaceutical and medical devices. Studies that had at least an English abstract were included in the evaluation. The results of the selected databases were entered into the Endnote Software (X.9.33 version). After removing duplicate studies, the titles and abstracts were studied. After unrelated studies were removed, the full texts of the remaining studies were reviewed. Two authors individually performed the above steps. They also independently assessed the quality of the studies included using the STROBE checklist.

**Stage 4. Charting the data**

A datasheet was then used to extract the data. Data were extracted independently by two individuals. The information extracted included authors' names, year of publication, country of study, dimensions, and variables influencing the access to emerging technologies, evaluation methods, and techniques, and studies' title, language, perspective, and outcome index.
Stage 5, Collating, summarizing, and reporting the result

This stage of a scoping study involves collating, summarizing and reporting the results. At first, we summarized the main characteristics of the studies such as year of publication, country of origin, type of method used to assess an emerging technology in the early stage of development, quantitative or qualitative algorithms to assess, criteria used to make decisions and perspective of the studies. We also divided the studies according to the type of emerging technologies. Then, the included studies were counted and ordered chronologically in terms of the types of medical technologies. A clear distinction was made between identified methods and comparative analysis of included studies based on the main characteristics.

Results

This study which was a scoping review, included 10,578 records in total and 8 studies that were added manually. A total of 3,275 studies were excluded after duplicate records were excluded and 7,303 records remained for assessment.

After reviewing the titles/abstracts, 319 abstracts remained. Among them, 58 records were eligible after reading the full text, but 21 studies were excluded as they were not original, lacked data sufficiency or the full text, or were not related to the health system. Finally, 38 records met the inclusion/exclusion criteria (Fig. 1).

Most of the studies were conducted in the Netherlands (13 studies), Germany (6 studies), and UK (6 studies) and the other conducted in Belgium (2 studies), Switzerland (2 studies), Denmark (3 studies), Sweden (3 studies), United States (3 studies), New Zealand (1 study) and Korea (1 study). Among these, 23 studies focused on medical equipment and diagnostic tests, 7 studies on pharmaceuticals and 8 studies were related to all new technologies and not specifically to a distinct category of medical technologies. Table 1 provides more detailed information about the studies.

Five general approaches to evaluate new technologies were identified at an early stage of development. Overall, 27 studies evaluated technologies using the early HTA approach, 4 studies using the pro-HTA method, 2 studies using horizon scanning, 3 studies using priority-setting techniques, and 3 studies using forecasting methods. Figure 2 shows these studies based on the time of the study and the type of intervention. The figure shows that in recent years most of the researchers used the early HTA approach to assess the effectiveness of emerging medical technologies.

Methods used in evaluating emerging technologies

1- Early health technology assessment: This approach is often undertaken in the context of economic evaluation studies in combination with clinical trial development strategies. The main purpose of this model is to evaluate the cost and effectiveness of interventions in the early stages of development. The first study using this approach was published in 1993 by Clemens, et al. (7). A review of the literature from 1993 to 2006 shows that this approach has often been used in the evaluation of emerging drugs in stages 1 and 2 of clinical trials, suggesting an uncertainty of evidence in a clinical trial or suggestions to improve or stop further trials (7-11). Dong, Van Til, and Hjelmgren reported the results of medical device evaluation (12-14).
Methods of Assessing New Technologies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Published year</th>
<th>Country</th>
<th>Intervention</th>
<th>R &amp;D stage</th>
<th>Method</th>
<th>Technique of modeling</th>
<th>Perspective</th>
<th>Type of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kirsten J.M (31)</td>
<td>2017</td>
<td>USA</td>
<td>Diagnostic trajectory</td>
<td>Before trial</td>
<td>Early HTA</td>
<td>Headroom analysis</td>
<td>Stockholder</td>
<td>Observational study</td>
</tr>
<tr>
<td>Aris Angelis (32)</td>
<td>2017</td>
<td>UK</td>
<td>Medicines, medical devices and other health interventions</td>
<td>Market launch</td>
<td>Context of HTA</td>
<td>MCDA</td>
<td>Decision maker</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Kolominsky Rabas (5)</td>
<td>2016</td>
<td>Germany</td>
<td>Device (Mobile Stroke Units)</td>
<td>Pre trial</td>
<td>Pro-HTA</td>
<td>System Dynamics and agent base model</td>
<td>Decision maker</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Aastha Gupta (33)</td>
<td>2016</td>
<td>Switzerland</td>
<td>Medicine (anti-retroviral treatment Device (ART) (R))</td>
<td>Pre market</td>
<td>Forecast Analysis</td>
<td>Predict market shares</td>
<td>Decision maker</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Katarzyna Markiewicz (27)</td>
<td>2016</td>
<td>Netherlands</td>
<td>Technology available but not used</td>
<td>Early HTA</td>
<td>Headroom analysis</td>
<td>Decision tree $ expert elicitation</td>
<td>Manufacturers</td>
<td>Case study</td>
</tr>
<tr>
<td>Michelle MA Kip (34)</td>
<td>2016</td>
<td>Netherlands</td>
<td>triple biomarker test (copper, heart-type fatty acid binding protein, and high-sensitivity troponin (HsTn))</td>
<td>Technology available but not used</td>
<td>Early HTA</td>
<td>Societal</td>
<td>Observational study</td>
<td></td>
</tr>
<tr>
<td>Middelkamp H.H (35)</td>
<td>2016</td>
<td>Netherlands</td>
<td>Device (Organs-on-Chips) Medicine</td>
<td>Early stage of development</td>
<td>Early HTA</td>
<td>MCDA</td>
<td>Stockholders</td>
<td>Observational study</td>
</tr>
<tr>
<td>Isabel Pintmann (36)</td>
<td>2010</td>
<td>Germany</td>
<td>Clinical research</td>
<td>Early HTA</td>
<td>Early HTA</td>
<td>EVITA</td>
<td>Physicians and other professionals</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Jilles (37)</td>
<td>2016</td>
<td>Netherlands</td>
<td>Forty-one technologies (16 pharmaceuticals and 25 non-pharmaceuticals) were NGS-based molecular diagnostics</td>
<td>Premarket</td>
<td>Priority setting</td>
<td>Best-worst scaling</td>
<td>Stockholders</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Joosten SE (38)</td>
<td>2016</td>
<td>Netherlands</td>
<td>Technology available but not used</td>
<td>Early HTA</td>
<td>Scenario drafting, expert elicitation Delphi panel with experts</td>
<td>Societal</td>
<td>Observational study</td>
<td></td>
</tr>
<tr>
<td>Huigems SA (39)</td>
<td>2016</td>
<td>UK</td>
<td>Device (tissue-engineered heart valves)</td>
<td>Early stage clinical research</td>
<td>Early HTA</td>
<td>Delphi panel</td>
<td>Societal</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Alan Girling (40)</td>
<td>2015</td>
<td>UK</td>
<td>Device</td>
<td>Early HTA</td>
<td>Early HTA</td>
<td>Headroom analysis</td>
<td>Manufacturers</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Tommy S (41)</td>
<td>2015</td>
<td>Netherlands</td>
<td>Instant MSC Product accompanying Autologous Chondron Transplantation (CT) system</td>
<td>Early stage of trial</td>
<td>Early HTA</td>
<td>Markov model, headroom analysis</td>
<td>Societal</td>
<td>Observational study</td>
</tr>
<tr>
<td>Georg Ruile (42)</td>
<td>2015</td>
<td>Germany</td>
<td>Computed tomography (CT) system</td>
<td>Early stage of trial</td>
<td>Early HTA</td>
<td>PRO-HTA</td>
<td>Society</td>
<td>Observational study</td>
</tr>
<tr>
<td>Kolominsky Rabas (15)</td>
<td>2014</td>
<td>Germany</td>
<td>Sensor for managing pulmonary artery in heart failure patients</td>
<td>Implementation of a new device to guide health services planning</td>
<td>Pro-HTA</td>
<td>System dynamic</td>
<td>Societal</td>
<td>Observational study</td>
</tr>
<tr>
<td>Wieke Haakma (43)</td>
<td>2014</td>
<td>Switzerland</td>
<td>Photoacoustic mammography (PAM) imaging for detecting breast cancer</td>
<td>Early stage of development</td>
<td>Early HTA</td>
<td>Expert elicitation</td>
<td>Decision maker</td>
<td>Observational study</td>
</tr>
<tr>
<td>Marion Gantner (23)</td>
<td>2014</td>
<td>Germany</td>
<td>Prostate specific antigen test</td>
<td>Early research and concept phase of an idea and before major investments are made</td>
<td>Early HTA</td>
<td>EVITA</td>
<td>Stockholders</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Bengt Jonsson (44)</td>
<td>2014</td>
<td>Sweden</td>
<td>Medicine (pimelimumab for the treatment of metastatic melanoma)</td>
<td>Early development phases</td>
<td>Early HTA</td>
<td>Markov model</td>
<td>Decision maker</td>
<td>Descriptive</td>
</tr>
</tbody>
</table>

This means the beginning of a new paradigm in the early HTA strategy, which provides adequate knowledge along with reimbursement and regulatory approaches for consumers and suppliers through the incorporation of the health system and industry perspectives. Based on the study results, this method uses various techniques to test technologies which are briefly listed in Table 2.

2- Pro-HTA: The primary purpose of pro-HTA is to evaluate emerging medical technologies from the perspective of health systems and technology makers. By simulating the potential impacts of new technologies, this model identifies the potentials and shortcomings of these technologies in the health system and seeks to predict the potential of the product in the future market. The main dif-
difference between this approach with early HTA and horizon scanning is that by simulating the system, it explores the potential benefits and disadvantages of using pre-production technology. In fact, by integrating technologies and processes into simulation scenarios, it depicts the effects of technologies on stakeholders, processes, and reimbursements throughout the system (15).

3- Horizon scanning: Horizon scanning studies are part of a broader field of health technology assessment. By determining priorities and the most important technologies for evaluation, and ultimately the evaluation of treatments among the selected technologies, provides health policy-makers with the information needed to make decisions. Initial evaluation includes information such as aspects of safety, effectiveness, and financial, organizational, ethical, and other factors related to the anticipation of new technology releases.

The main difference between health technology assessment and the horizon scanning system is that the latter focuses mainly on evaluating and prioritizing new products at different stages of their fabrication, while health technology assessment studies focus on evaluating newly

Table 1. Ctd

<table>
<thead>
<tr>
<th>Authors</th>
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<th>Intervention</th>
<th>R&amp;D stage</th>
<th>Method</th>
<th>Technique of modeling</th>
<th>Perspective</th>
<th>Type of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qi Cao (45)</td>
<td>2013</td>
<td>Netherlands</td>
<td>Device (point-of-care testing (POCT)) Markers for Prostate Cancer Screening &amp; Mobile Stroke Units</td>
<td>Market launch</td>
<td>Early HTA</td>
<td>Headroom analysis, Markov model, expert elicitation</td>
<td>Stockholders</td>
<td>Case study</td>
</tr>
<tr>
<td>Anatoli Djanatliev (22)</td>
<td>2013</td>
<td>Germany</td>
<td>Before the design and development phase has started Early stages of development Early stages of promising new technologies</td>
<td>Pro HTA</td>
<td>Early HTA</td>
<td>Scenario analyzing</td>
<td>Decision maker</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Valesca P. Reté (46)</td>
<td>2013</td>
<td>Netherlands</td>
<td>(70G-FFT), (70G-PAR) 70-gene signature for breast cancer</td>
<td>early HTA Early HTA Early HTA</td>
<td>Markov model</td>
<td>Stockholders</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Wim H van Harten (26)</td>
<td>2012</td>
<td>Netherlands</td>
<td>Early stages of development Early stages of promising new technologies</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Markov model</td>
<td>Stockholders</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Douwe Postmus (47)</td>
<td>2011</td>
<td>Netherlands</td>
<td>Early stages of promising new technologies</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Markov model</td>
<td>Stockholders</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Ofr A (61)</td>
<td>2010</td>
<td>New Zealand</td>
<td>Technology available but not used Early stages of development</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Engineering risk analysis</td>
<td>Industry</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Pietzsch JB (49)</td>
<td>2008</td>
<td>USA</td>
<td>Device</td>
<td>As early as possible in the development cycle</td>
<td>Market launch Early HTA Early HTA</td>
<td>Headroom analysis, and revenue analysis</td>
<td>Industry</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Emma Cosh (50)</td>
<td>2007</td>
<td>UK</td>
<td>Technology</td>
<td>As early as possible in the development cycle</td>
<td>Market launch Early HTA Early HTA</td>
<td>Decision maker</td>
<td>Qualitative</td>
<td></td>
</tr>
<tr>
<td>Filip Mussen (51)</td>
<td>2007</td>
<td>Belgium</td>
<td>Medicine</td>
<td>Technology available but not used</td>
<td>Priority setting Early HTA Early HTA</td>
<td>MCDA Decision maker</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Hengjin Dong (52)</td>
<td>2006</td>
<td>UK</td>
<td>Knee replacement (TKR) using computer-assisted surgery</td>
<td>Early in the lifecycle of new technologies</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Markov model Decision maker</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Karla Douw (53)</td>
<td>2006</td>
<td>Denmark</td>
<td>Medicine or no medicine</td>
<td>Early stage of clinical trial (1-2-3)</td>
<td>Horizon scanning systems Horizon scanning systems Horizon scanning systems</td>
<td>Delphi panels Decision maker</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Karla Douw (54)</td>
<td>2006</td>
<td>Denmark</td>
<td>Device</td>
<td>1,2,3 clinical trial</td>
<td>Stage II trial</td>
<td>Horizon scanning</td>
<td>MCDA Societal</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Van Til JA (55)</td>
<td>2006</td>
<td>Netherlands</td>
<td>Percutaneously neuroromuscular electrical stimulation Cell replacement therapy in Parkinson’s disease</td>
<td>Early stage in trial</td>
<td>Early HTA Early HTA Early HTA</td>
<td>-</td>
<td>Society</td>
<td>Clinical Trial</td>
</tr>
<tr>
<td>Jonas Hjelmgren (56)</td>
<td>2006</td>
<td>Sweden</td>
<td>Medicine</td>
<td>Early stage in trial</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Clinical trial simulation, option pricing, investment appraisal, threshold analysis, and value of information analysis</td>
<td>Stockholders</td>
<td>Observational study</td>
</tr>
<tr>
<td>Paul Miller (57)</td>
<td>2005</td>
<td>Sweden</td>
<td>Medicine</td>
<td>Early development phases</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Clinical trial simulation, option pricing, investment appraisal, threshold analysis, and value of information analysis</td>
<td>Stockholders</td>
<td>Observational study</td>
</tr>
<tr>
<td>Robert Phaal (58)</td>
<td>2004</td>
<td>UK</td>
<td>Every technology</td>
<td>Early stage of development</td>
<td>Forecasting</td>
<td>Road mapping Industry, multiorganizational</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Karla Douw (59)</td>
<td>2004</td>
<td>Denmark</td>
<td>Medicine or no medicine</td>
<td>Early stage of development</td>
<td>Early HTA Early HTA Early HTA</td>
<td>Clinical experts Decision maker</td>
<td>Descriptive</td>
<td></td>
</tr>
<tr>
<td>Jeong-Dong LeeT (60)</td>
<td>2003</td>
<td>Korea</td>
<td>Multigenerational product</td>
<td>Early stage of development</td>
<td>Forecasting</td>
<td>Time-series analysis &amp; discrete choice models discrete,</td>
<td>Consumer</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Joseph A (61)</td>
<td>2001</td>
<td>USA</td>
<td>Medicine</td>
<td>Early development phases</td>
<td>Early HTA Early HTA Early HTA</td>
<td>-</td>
<td>-</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Lieven Anne-mans (62)</td>
<td>2000</td>
<td>Belgium</td>
<td>Medicine</td>
<td>Early development phases</td>
<td>Early HTA Early HTA Early HTA</td>
<td>-</td>
<td>-</td>
<td>Descriptive</td>
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made technologies. The general steps of this approach include: 1. Identification: identification of emerging pharmaceutical and non-pharmaceutical technologies. 2. Filtering: Selecting the most important and most efficient technologies from the experts’ point of view. 3. Priority setting: Prioritize these technologies based on different evaluation criteria from the perspective of each country. 4. Assessment: using evaluation methods for comparing two drugs or interventions in two different therapies (16).

4- Priority setting: Given the accelerating development of technology and the increasing demand for services as well as resource limitations, the past decade has experienced the increasing use of rational and transparent approaches in service prioritization (17). Therefore, this method identifies a wide range of accessible services by prioritizing services according to some specific criteria, including demographic factors, epidemiology, infrastructure, reimbursement mechanisms, costs, and potential benefits of service utilization. As mentioned earlier, this technique is one of the HSS (Horizon Scanning System) steps, but some studies have used it separately to evaluate technologies (18).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Various techniques are used in different approaches to evaluate technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>Technique</td>
</tr>
<tr>
<td>Early HTA</td>
<td>EVITA*</td>
</tr>
<tr>
<td>Headroom analysis</td>
<td>It is a QALY* approach that evaluates emerging technologies by considering the maximum potential of the effect of technology, the maximum willingness to pay (WTP) for this EFFECT, and decreases the potential costs involved in applying this technology.</td>
</tr>
<tr>
<td>Expert elicitation</td>
<td>It is a method to measure unknown parameters for evaluating a new technology at the early stage of development from the experts' point of view.</td>
</tr>
<tr>
<td>Scenario analyzing</td>
<td>In this technique, a team of experts and analysts delineate the path and dissemination of technologies across multiple scenarios and then monitor and predict these technologies using specific criteria such as efficiency, logistics, ethical/legal aspects, patient centeredness and cost-effectiveness at the early stage of development.</td>
</tr>
<tr>
<td>Engineering risk analysis</td>
<td>This technique assesses the risk of failure by evaluating new technology compared to existing alternatives, and this method ultimately depends on the decision maker's preferences and his degree of risk taking.</td>
</tr>
<tr>
<td>MCDA</td>
<td>In these methods, several options are compared against multiple criteria; the best option or the most appropriate order of options is selected. MADM methods, based on mathematical reasoning, determine the best decision-making option out of the available options by prioritizing them.</td>
</tr>
<tr>
<td>Markov</td>
<td>In this model, disease states are used to represent all the possible consequences of an intervention. These models are fully exclusive. So, every individual can be in just one disease state at any time.</td>
</tr>
<tr>
<td>System dynamic</td>
<td>Dynamic modeling is a simulation of the real world that is presented in mathematical terms with nonlinear relationships of the real world.</td>
</tr>
</tbody>
</table>

*QALY: Quality Adjusted Life Years/MCDA: Multiple Criteria Decision Analysis

1 Evaluation of Pharmaceutical Innovation with regard to Therapeutic Advantage

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Table 2 Ctd

<table>
<thead>
<tr>
<th>Modelling</th>
<th>Technique</th>
<th>Definition</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro-HTA</td>
<td>Clinical trial simulation</td>
<td>This model uses mathematical synthesis to integrate simultaneously models of pharmacokinetics and pharmacodynamics drug action, disease progression, placebo effects, and patient variability.</td>
<td>(57)</td>
</tr>
<tr>
<td></td>
<td>Best &amp; worse scaling</td>
<td>Having chosen the list of objects, the researcher presents choice sets of these to respondents to get the best and worst option data.</td>
<td>(57)</td>
</tr>
<tr>
<td>Priority setting</td>
<td>conjoint-analysis</td>
<td>This is a survey-based statistical method used in market research. In fact, this technique is based on evaluating people's preferences of technologies based on specific criteria such as potential benefits, processes, organizational aspects.</td>
<td>(48)</td>
</tr>
<tr>
<td>Horizon scanning</td>
<td>Delphi MCDA</td>
<td>The insights of experts are combined on a given question.</td>
<td>(53)</td>
</tr>
<tr>
<td></td>
<td>Road mapping</td>
<td>This method is described in the early HTA approach.</td>
<td>(54)</td>
</tr>
<tr>
<td>Forecasting</td>
<td>Discrete-event simulation</td>
<td>This method assesses potential opportunities and threats for technology and market development during product development and delivery. Road-mapping has great potential in technology development and provides companies with relevant information about their manufacturing processes and tools.</td>
<td>(19)</td>
</tr>
</tbody>
</table>

*QALY: Quality Adjusted Life Years/MCDA: Multiple Criteria Decision Analysis

5- Forecasting: This method is often used for industry. It attempts to graphically illustrate the future relationship between services, status, and the developed and under developing market variables. Once the future status and the path of technology are clear, there will be appropriate and timely feedback to continue the process of product development (19).

The perspective of the included studies

Conventional HTA approaches are limited in the process of health care decision-making in integrating a variety of preferences and stakeholder's perspectives (20). In other words, patient and public involvement are more focused and are not able to identify and respond to all stakeholders. According to Danie's ethical framework of 'accountability for reasonableness, all reasons and criteria for funding health care should be accessible to all stakeholders (21).

Therefore, with different stakeholders in the health system, in decision-making about new technologies, the

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views of different stakeholders must be considered at the same time and when there is agreement on access to new technology from a variety of perspectives, including health, insurance, industry and the public, a decision that helps products develop and are based on real community’s demand and prevent waste of resources is helpful (5, 22, 23).

To this end, today, newer approaches such as pro-HTA, early HTA, horizon scanning, priority setting are being tried by different stakeholders to evaluate new technologies using different techniques. Among the studies investigated in the present study, 10 studies were conducted from the decision maker’s perspective, 1 from the physician’s perspective, 7 from the societal perspective, 9 from the stockholders’ perspective, 6 from the industry perspective, and one from the patient’s perspective.

Criteria extracted from studies on emerging technologies evaluation

To evaluate emerging technologies in the studies under consideration, different criteria have been taken into account, depending on the study’s perspective. In this study, we tried to classify these criteria into larger dimensions by examining and aggregating them (Table 3).

Among the studies reviewed, 26 studies examined healthcare outcome criteria, 12 studies examined patient-relevant criteria, 17 studies examined technology relevant criteria, 10 studies examined socioeconomic criteria, 6 studies examined innovation level, 8 studies examined population dynamic, 8 studies examined environmental variables, and 9 studies examined financing criteria in their evaluations of technologies.

The studies used different criteria in their evaluations, but most studies used criteria such as the cost of access to new technology, budget impact, the burden of disease, Willingness To Pay (WTP), safety, effectiveness, and availability. The least attention is paid to technology-level criteria.

Discussion

The limitations of health resources have led researchers to consider the clinical and economic implications of investing in new technologies. Health Technology Assessment is used as a tool to ensure the maximum health of the community and prevent the emergence of inefficient technologies. It helps to ensure that the new technology is good value for money as long as it is ready to enter the clinical practice. However, such calculations at the time of the introduction of new technology into the treatment process will not help to improve the monetary value of the technology by making changes to the new technology. To prevent the loss of R&D investments for new technologies, developers have proposed to evaluate the economic and clinical impacts of technology at an early stage of development.

In this study, 38 studies were found to meet the inclusion criteria, which were then examined based on their different evaluation techniques and perspectives and the criteria for technology monitoring. Five general evaluation methods for monitoring technologies (pharmaceutical and non-pharmaceutical) in the early stages of development were found, including Pro-HTA, Early-HTA, forecasting, and HSS. These methods are performed at or before the early clinical trial. Since at this stage of technology development, scientific evidence is limited, expert elicitation techniques are used alongside the methods to complete the evidence.

The findings showed that pro-HTA, early HTA, and HSS models, in their evaluations, often take into account the various stakeholders in the health system. They develop technology when there is an agreement on deciding to introduce new technology in terms of health, insurance, industry, and people’s perspective. So this method develops products that are based on the community’s real demand and help prevent the waste of resources (2, 15, 23).

Chronologically, the pro-HTA method seems more recent than the other methods. Because of the complexity and lengthy scenarios of investigating the effects of emerging technology, the dynamic simulation models used in the PRO-HTA method have become increasingly popular.

Most of the studies we considered used the early HTA method. The Pro HTA method, taking into account various influential criteria in terms of industry, health system, people, and insurance of access to technology, helps corporate managers and the health system make decisions while simulating the results of an emerging product to optimize or reject an innovative product to avoid inappropriate investments (24, 25).

The early HTA approach is principally based on the concept of HTA, and the main difference is at their starting point of analysis. The HTA method is assessed after the technology is completed and before entering the treatment process, while in the early HTA method, it performs analysis during the technology research and development stages. In other words, the HTA approach is based on the results of evidence-based studies, so it is possible to use HTA after the development or implementation of new technology, while the early HTA evaluates technology at the early stage of product development. HSS also prioritizes new developing technologies.

Hartz et al. (2008) conducted the first systematic review in 2008 to identify methods for evaluating technologies at an early stage of development, which was in line with the purpose of the present study. It included 56 studies on pharmaceutical technology assessment and 27 studies on medical devices. In the present study, there were 7 studies on pharmaceutical products, 24 studies on medical devices, and 7 studies on evaluating both technologies.

Retele et al. (2009) studied the methods and results of nanotechnology evaluation in cancer care in the early stages of development and in the process of their diffusion. They found that most studies focused on the regulatory and safety (environmental) aspects and did not provide any structural assessment of dynamics, health economics, or organizational aspects (26).

Katarzyna Markiewicz (2014), in a study from 1996 to 2013, identified different techniques in technology assessment and evaluation. Compared to Hartz’s study, they focused on medical devices and identified some qualita-
tive and quantitative methods emphasizing that these techniques must be implemented before the product can be fully developed (27).

Maarten J. Ijzerman et al. identified 10 methods for assessing medical technologies at an early phase before market launch. They named them early HTA methods, while some of these techniques did not follow the principles of early HTA, which had been defined by Pietzsch and Pat e-Cornell (2008). They defined early HTA on the principles of economic evaluation in the health economics discipline. In this definition, early HTA assesses the safety, effectiveness and cost-effectiveness of new medical technology (28). But MCDA or Horizon scanning techniques are developed to trace new technologies for broader dimensions previously defined for early HTA. MCDA captures some criteria in addition to safety, clinical effectiveness and cost-effectiveness of new technology such as the severity of disease, size of targeted population and equity consideration (29, 30). Horizon scanning not only focused on potential safety, clinical effectiveness and economic impact of emerging technologies but also considered other impacts of emerging technologies. To deal with the above reasons, we revisited the classification for methods in the previous study (28).

Claudia Wild et al. also conducted a systematic review to identify the countries using the HSS approach and its process and practice. Finally, 13 countries were identified that studied the same processes such as identification and filtering, prioritization, initial evaluation, diffusion, and monitoring of the technologies evaluated.

It is noteworthy that studies evaluating pharmaceutical products date back to 2000 and earlier. In recent years this assessment has shifted to medical devices. It could be due to shorter clinical trial lengths for medical devices compared to medicines and, as a result, easier appraisal and estimation of outcomes, the shorter life cycle of equipment, more predictable outcomes in product development compared to pharmaceutical products, more expensive equipment in most cases and consequent costs of technology (repairs, maintenance).

In the future, the use of early technology evaluation strategies such as Early HTA and pro-HTA will be more desirable given the constraints emerging from limited resources, increased demand, complex dynamics of disease, increased pressure on health systems, and increased uncertainty in R&D on the production of medical services. It is expected that the results of these studies will lead to value-dependent pricing.

This study faced some limitations. The timeframe of the present study was limited to studies that were published since 2000. We did not fully search grey literature to find relevant studies. We might have missed some studies which would be potentially included. However, systematic review studies indicate that a specific method to measure the economic and clinical impact of emerging technologies at the development stage has not been eliminated.

**Conclusion**

Given the limited financial resources of the health sector in most countries, to invest in the R&D sector in the development of emerging medical technologies, research should ensure that technology can be incorporated into the therapeutic process. Different methods were used to investigate the impacts of emerging medical technologies. Chronologically Pro-HTA methods are new ways for investigating emerging medical technologies beyond clinical and economic impacts. Assessing the feasibility of implementing Pro-HTA in real environments requires further research.

**Conflict of Interests**

The authors declare that they have no competing interests.

**References**

Methods of Assessing New Technologies

57. Miller P. Role of pharmacoeconomic analysis in R&D decision
Methods of Assessing New Technologies

Appendix. Search strategy in Pubmed:

#1 simulat* [T/A] (536,040)
#2 forecast [T/A] (8,918)
#3 forecasting [MeSH Subheading] (388,878)
#4 forecasting [All Fields] (652,477)
#5 future [All Fields] (886,484)
#6 emerging assessment [All Fields] (170,413)
#7 foresight process* [T/A] (303)
#8 Technology Foresight [T/A] (717)
#9 health technology assessment [T/A] (4,857)
#10 horizon scanning [T/A] (195)
#11 pro HTA[All Fields] (45)
#12 HTA [T/A] (3,084)
#13 dynamic model [T/A] (4,430)
#14 prospective assessment [T/A] (1,584)
#15 trends [MeSH Subheading] (388,787)
#16 prospective simulation [T/A] (36)
#17 early assessment [T/A] (2,445)
#18 assessment, biomedical technology [MeSH Terms] (11,143)
#19 health technology [MeSH Terms] (14,210)
#20 computer simulation [MeSH Subheading] (238,945)
#21 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20) (1,681,216)
#22 pharmaceutical innovation [T/A] (229)
#23 pharmaceutical diffusion [T/A] (23,207)
#24 health technology diffusion [T/A] (4)
#25 emerging diffusion [T/A] (7,029)
#26 emerging drug [T/A] (795)
#27 new drug [T/A] (17,173)
#28 new medicine [T/A] (460)
#29 drug entity [T/A] (85)
#30 medicine entity [T/A] (22,869)
#31 emerging health technology [T/A] (12)
#32 healthcare innovation [T/A] (25)
#33 medical device* [T/A] (15,393)
#34 innovation diffusion [MeSH Subheading] (19,985)
#35 approval, new device [MeSH Subheading] (2,944)
#36 approval, new drug [MeSH Subheading] (15,530)
#37 (#24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36) (76,894)
#38 ("2020/08/31"[Date - Completion]: "2020/08/30"[Date - Completion]) (17,885,956)
#39 (#23 AND #39 #40) (11,417)