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Telemedicine Research from Big Bang to 2022

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Abstract. The Clinical Information Systems (CIS) section of the IMIA Yearbook of Medical Informatics systematically screens about 2,500 publications from more than 1,000 journals annually to find the best CIS publications. The editors of the CIS section have noticed a trend toward patient-centered care supported by AI and machine learning and increased research in cross-institutional data sharing, particularly in telemedicine. As a result, they adjusted their search query to include the MeSH term "telemedicine." As a preliminary step and to get a sense of the historical development of telemedicine research activity, they performed a bibliometric analysis of all previously published papers in PubMed indexed with the tag "Telemedicine" as MeSH Major Topic. They retrieved 29,289 publications from 1976 to 2022 and used their titles and abstracts to create a bibliometric network that visualizes the most relevant terms, their frequency and relationship to each other, and the chronological sequence of their publication. The development over time also shows a clear move toward patient-centeredness. Interestingly, the term "Covid," which has only recently come into use, takes on a central role in the network.

Keywords. Telemedicine, research trends, bibliometric analysis

1. Introduction

We have been responsible for the Clinical Information Systems (CIS) section of the IMIA Yearbook of Medical Informatics for almost ten years. Each year we search PubMed and Web of Science with a standardized query to systematically screen the CIS field's publication landscape and find candidates to select the best CIS publications of the recent year. Approximately 2,500 publications from more than 1,000 different journals are thus screened annually by the CIS section editors.

In addition to this search and the manual screening, we regularly visualize the publication landscape through bibliometric analyses. In recent years, there has been a clear trend away from "simple" clinical documentation towards patient-centered but artificial intelligence and machine learning-supported patient care [1–5]. The COVID pandemic has tremendously impacted the publication landscape in the last few years [6,7].

In addition, we have noticed that trans-institutional data sharing is an important field of research. However, not only the sharing of data but also its use in telemedicine applications is a clear trend. Since the area of telemedicine was not or not sufficiently

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covered in the previously used systematic query, we decided to explicitly include the MeSH term "Telemedicine" in the query.

As a preliminary to this, and to get a picture of the historical development of research activity in telemedicine, we performed a bibliometric analysis of all previously published papers in PubMed indexed with the tag "Telemedicine[MeSH Major Topic]".

2. Methods

On January 4, 2023, we searched PubMed with the search term "(Telemedicine[MeSH Major Topic] AND hasabstract)". We then exported the information on the resulting publications in PubMed format to a text file. As PubMed only allows the export of 10,000 entries at once, we repeated this step to extract information on all found papers.

To get a first overview of the content of the publications, we extracted all authors' keywords from the PubMed File and created a pivot table sorted by frequency. Based on this table, we created a tag cloud from the most frequent 400 keywords.

We then used VOSviewer, a software tool for constructing and visualizing bibliometric networks [8], to calculate and visualize a bibliometric map to get a deeper insight into the content of the publications. More details concerning the clustering and map layouting techniques can be found in [9].

We used the titles and abstracts of all publications and chose a binary count, meaning that each term was counted only once per publication, regardless of how many times it was used there. The selection threshold was set at 50, meaning that a term must appear in at least 50 publications to be included in the network. We also used a thesaurus that we developed over the last years as CIS section editors to filter out stop words and homogenize terms (e.g., singular and plural of terms or to standardize abbreviations and spelled-out terms).

3. Results

With our query, we retrieved 29,289 publications. The first publication was from 1976. A publication by Cechner and Carter in the American journal of clinical pathology titled "Storage and retrieval of SNOP-coded pathologic diagnoses using offsite computing and optical character recognizing systems" [10].

This paper marks the big bang, so to speak, in the universe of telemedicine publications. (At least, if we look at the publications with an abstract. Without this restriction, a publication by W. Darrah titled "A mobile health service for migrant families" in Nursing Outlook from 1962 can be found [11]. Unfortunately, we could not retrieve the original paper.)

Over the next 15 years, there were sporadic publications, and it was not until the early 1990s that there was a steady increase in the number of papers. In 1991 there were 3; in 1992, 21; and 28 in 1993, the year when the term "Telemedicine", defined as "Delivery of health services via remote telecommunications. This includes interactive consultative and diagnostic services." was added to the MeSH catalog. Since then, exponential development of publication numbers can be observed.

We could extract 78,608 authors' keywords from the PubMed file, of which 27,710 were used only once. The most frequent keyword was "telemedicine" (n=4,798), followed by "mhealth" (n=2,346), "ehealth" (n=1,698), "COVID-19" (1,654), and

"digital health (n=457)". The tag cloud illustrating the most frequent authors' keywords (the top 400 keywords are shown) is depicted in Figure 1.

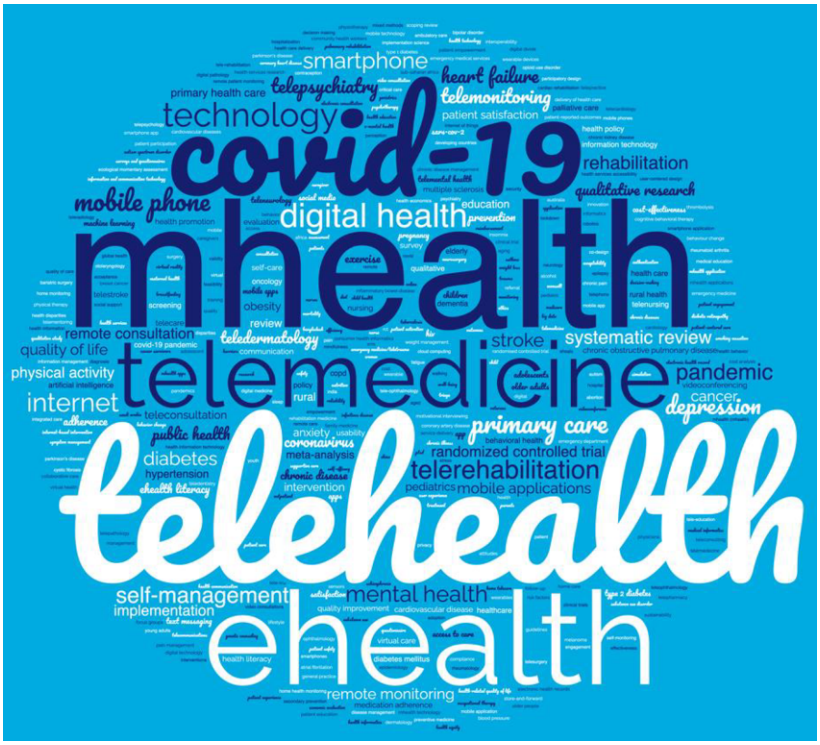

Figure 1: Tag cloud illustrating the most frequent authors' keywords (top 400 out of n=78,608) within the 29,289 papers from the query result set.

From the titles and abstracts of the 29,289 publications, 343,248 distinct terms could be extracted. Of them, 2,627 met the selection threshold. For each of these terms, a relevance score was calculated. Based on this score, the most relevant terms are selected for the network. We left the default setting and selected the most relevant 60 percent resulting in 1,576 terms.

The term intervention was the most frequent (n=5,831), followed in second place by COVID with n=3,785. The mean publication year was calculated for each term and color-coded to represent the temporal course of the publications. Purple corresponds to "old" terms, while "new" or more recently published terms are yellow.

Figure 2 depicts the resulting network as a Co-occurrence map of the terms.

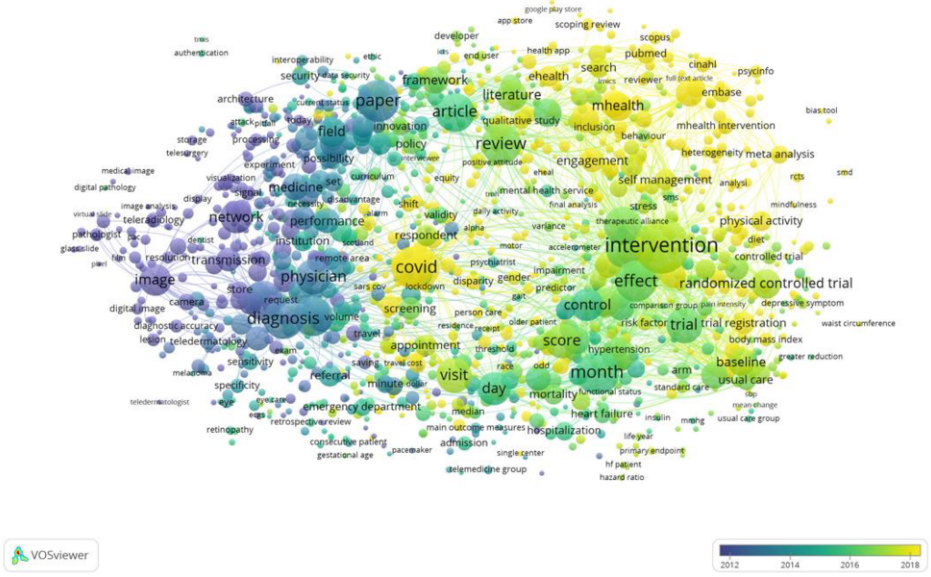

Figure 2. Co-occurrence map of the Top-1,500 terms (n=1,576) from the titles and abstracts of the 29,289 telemedicine papers published in Pubmed from 1976 to 2022. Only terms we found in at least 50 different papers were included in the analysis. Node size corresponds to the frequency of the terms (binary count, once per paper, intervention: n=5,831). Edges indicate co-occurrence (only the top 1,000 of 588,382 edges are shown). The distance of nodes corresponds to the association strength of the terms within the texts. Colors represent the average publication year per term. The network was created with VOSviewer [8].

The change over time in the terms used is very clear. While "old" terms highlight technological aspects such as "image", "network", "transmission", etc. or concrete application domains of telemedicine, such as "teleradiology", "teledermatology", or "telepathology", the new terms, in addition to terms describing study types, focus on patient-related aspects of telemedicine interventions, such as "inclusion", "behavior", "engagement" or "self-management". The mobile app sector is also clearly visible. Particularly impressive is the central position and the extent of the term "Covid", which has only been used recently.

4. Discussion

Our analysis was able to show the long history of publications in the field of telemedicine. Looking at the publications without abstracts, the first telemedicine publication was in 1962. Including an abstract, we found the first in 1976. Since then, exponential development has been shown.

The method of bibliometric analysis and visualization of terms in titles and abstracts of studies is very suitable for getting a quick overview of the content of a large number of publications.

Very interesting is the possibility of overlay visualization, which visualizes the temporal dimension. By calculating and color-coding the average publication year for each term, one can quickly get an overview of the development over time in the publication process. Past and current trends in research can thus be easily identified.

Of course, the method only provides a rough overview, and many details are lost. Thus, to gain deeper insights into the content of individual papers, one must resort to other systematic literature review methods.

However, this was never the claim of the present work. But it helped us to decide to expand the search query for the CIS section of the IMIA Yearbook of Medical informatics to include telemedicine.

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