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Telemedicine – A bibliometric and content analysis of 17,932 publication records

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ABSTRACT

Objectives: We aimed to provide an up-to-date contemporary bibliometric view of the telemedicine and telehealth literature and a longitudinal analysis of changes in content themes.

Methods: Software tools were used to extract and process MEDLINE entries. Frequencies of papers by year of publication and outlet were calculated, ranked, charted and tabulated. Frequency of publication by author was also calculated, ranked and tabulated. The process was repeated for two time periods to examine change: (i) 1970–1995 and (ii) 2009–2013. Content analysis of abstracts was conducted and tag clouds were generated. This visual representation was used to identify key words and prominent themes.

Results: 17,932 records relating to articles published in 2523 unique outlets were analyzed. In the cumulative literature, 3152 (18%) articles were published in specialist telemedicine journals while most articles (14,780 [82%]) were published in mainstream outlets. This pattern was observed in both epochs. Clinical journals were not highly represented. Over time 46,066 unique authors have contributed to the field, with 21,109 of them publishing in the period 2009–2013.

Discussion: Telemedicine is a large and growing field with most publication occurring outside of the specialist journals. Content analysis suggested a change of focus from the technical to the clinical between the two epochs. As a healthcare setting, the home also appears to be emergent.

Conclusion: This study updates the findings of previous studies. The emphasis within the literature suggests a move from technical issues to clinical applications and evaluation. The maturity of the field and its accessibility to clinicians and policy makers remains unclear.

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1. Introduction

Bibliometric analysis can provide useful insights into a body of literature and several such analyses have been conducted in the domain of telemedicine and telehealth [1–6].

The earliest study, by Moser et al., and published in 2004 examined the relationship between telemedicine publication output, as indexed in MEDLINE between 1964 and 2003, and gross national product per capita, human development index and the number of personal computers per 1000 residents [5]. At the time of that study, 37% of the current body of literature had been published.

A year later, Demiris and Tao examined the country of origin, study types and MEDLINE Medical Subject Headings (MeSH) terms relating to papers published in the two specialist peer-reviewed telemedicine journals, the *Journal of Telemedicine and Telecare* (JTT) and the *Telemedicine Journal and eHealth* (TJeH) [3].

In 2010, Della Mea used bibliometric tools to explore the published literature relating to telepathology [2] and in 2012, Fatehi and Wootton examined trends in the use of the terms telemedicine, telehealth and e-health within the international literature [4].

The most recent bibliometric study of the field of telemedicine was conducted by Askari et al. and published in 2014 [1]. The authors used the Science Citation Index Expanded (SCIE, Thomson Reuters) to identify highly-cited articles within the JTT and TJeH. However, its applicability to the field as a whole was limited because publications in the specialist journals only accounted for 17% of total publications in the field (82.5% of articles were published elsewhere) and because SCIE is not comprehensive in its coverage of citations [7].

The most comprehensive examination of the telemedicine literature was conducted by Whan et al. in 2006 [6]. This study examined publication trends together with citation trends, both in the general literature and within the specialized JTT and TJeH. Since this article was published, the body of literature on this subject has almost doubled.

The rationale for this new analysis is twofold: firstly, the literature base has doubled in size since the last comprehensive analysis by Whan et al. [6], hence a follow-up examination is warranted; secondly, with advances in technology and the maturing of the discipline, it is likely that the themes discussed within the relevant literature have changed over time: that is, issues of prime importance to the pioneers of telemedicine in the context of the period, may be quite different to those of contemporary times. However, we are not aware of any studies that have examined content, or longitudinal changes in content within the telemedicine literature. Such an examination would be useful to identify themes that are current and emerging, and those which are no longer of significant interest.

Thus, the present study aimed to provide a contemporary bibliometric view of the telemedicine and telehealth literature together with a longitudinal analysis of changes in the content themes discussed within it.

2. Methods

We used PubMed as a single source for this study. While other databases have greater coverage, PubMed is the most comprehensive index of peer reviewed literature available that allows open programmatic access.

We developed a set of software tools to access and process MEDLINE records via the PubMed Entrez Programming Utilities (E-Utilities) interface [8]. Our software programmatically executes searches on the PubMed database, extracts results in MEDLINE format and produces summary bibliometric information by author, outlet, title content and abstract content using the Author (AU), Full Author (FAU), Journal Title Abbreviation (TA), Title (TI) and Abstract (AB) MEDLINE data elements [9].

2.1. Search epochs

Using our software tools, we conducted searches for three epochs: *all-time*; *early* and *contemporary*. The all-time epoch included the cumulative literature to-date. For the early epoch, we captured articles published during the pioneering period of telemedicine, before any substantial growth of the field occurred. Because there was a rapid rise in the number of annual publications from 1995 (visible in the distribution shown in Fig. 1 and coinciding with the launch of the JTT and TJeH), we defined the *early epoch* to include articles published on or before 31st December 1995). For the *contemporary* epoch, to reflect changes in technology and the maturity of the field, we considered a five year window to be appropriate and hence included articles published in the last five complete years of publication records; 1st January 2009–31st December 2013). We included all publication types indexed in PubMed. The search strings are listed in Table 1; all searches were conducted in June 2014.

2.2. Longitudinal publication trend

To summarize the general publication trend within the field we charted the frequency of articles by year of publication for the *all-time* epoch.

2.3. Outlets

Using our software tools, the frequency of papers by publication outlet was calculated for each epoch. Outlets were then ranked by number of publications and the top 20 results were tabulated.

To assess the extent with which telemedicine was becoming mainstream, we performed a subgroup analysis of the JTT and TJeH specialist outlets to determine the proportion of articles published in the specialist versus non-specialist (i.e. mainstream) outlets. We compared proportions between the early and contemporary epochs to examine any change over time.

While some outlets have combined over the years, we calculated article counts and rankings based on the publication name, at the time of publication, as described within the

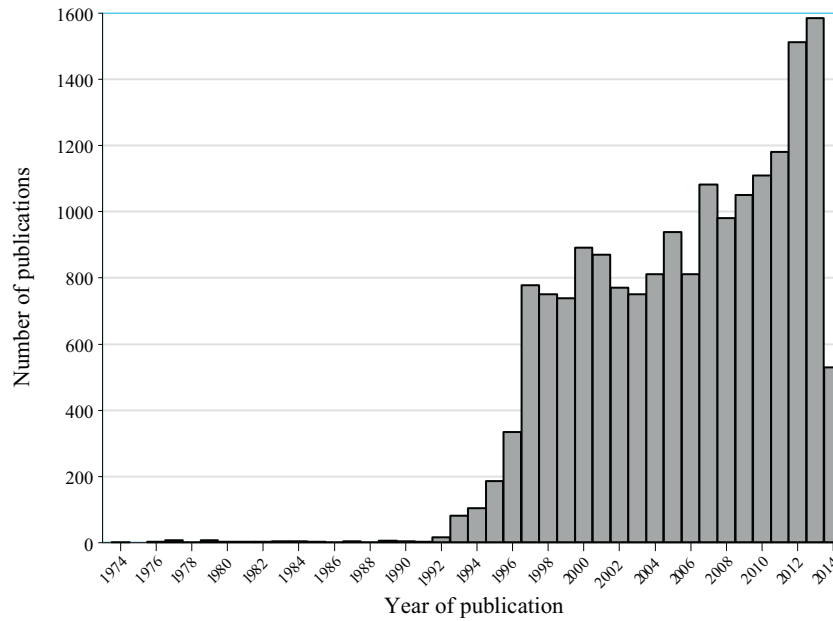


Fig. 1 – Distribution of publications by year (n = 17,932).

PubMed database. That is, no effort was made to adjust for the merging of outlets in our analysis.

2.4. Authors

Our software ranked authors by their total number of publications within each epoch. Unique authors were identified by the MEDLINE FAU data elements. Checks and adjustments for authors who publish under multiple names (e.g. with/without middle initial) were conducted manually after automatic ranking. Our ranking approach varied by epoch: For the all-time epoch, we tabulated the top 30 authors. For the early epoch, because most authors had few publications, we tabulated only the top authors with five or more publications. In the contemporary epoch, we ranked the authors who had contributed to a total of 10 or more articles. To explore the effect of editorials we then re-ranked authors who had contributed to a total of 10 or

more articles, with editorials excluded. The final results were manually double checked by one author (NRA) and a research assistant.

2.5. Content analysis

Article abstracts, where available, were imported into Nvivo 10 (QSR International) and word frequency distributions analyses were performed. The automated similarity setting (set at 25%) was used to group stemmed and similar words together. The analyses were performed for each epoch.

Tag clouds were generated for each query. Tag clouds provide visual description of a body of material whereby the size of each word (“tag”) is proportional to the frequency of its occurrence within the source material.

This visual representation was used to identify key words and prominent themes.

Table 1 – PubMed search terms for each epoch.

Epoch	Query
All-time	“telemedicine”[MeSH Terms] OR telemedicine[TW] OR telehealth[TW] OR telecare[TW] OR “remote consultation”[MeSH Terms] OR videoconference[TW] OR “video conference”[TW] OR “video conferencing”[TW] OR “videoconferencing”[TW]
Early	“telemedicine”[MeSH Terms] OR telemedicine[TW] OR telehealth[TW] OR telecare[TW] OR “remote consultation”[MeSH Terms] OR videoconference[TW] OR “video conference”[TW] OR “video conferencing”[TW] OR “videoconferencing”[TW] AND (“1970/01/01”[PDAT]: “1995/12/31”[PDAT])
Contemporary	“telemedicine”[MeSH Terms] OR telemedicine[TW] OR telehealth[TW] OR telecare[TW] OR “remote consultation”[MeSH Terms] OR videoconference[TW] OR “video conference”[TW] OR “video conferencing”[TW] OR “videoconferencing”[TW] AND (“2009/01/01”[PDAT]: “2013/12/31”[PDAT])
Contemporary (excluding Editorials)	(“telemedicine”[MeSH Terms] OR telemedicine[TW] OR telehealth[TW] OR telecare[TW] OR “remote consultation”[MeSH Terms] OR videoconference[TW] OR “video conference”[TW] OR “video conferencing”[TW] OR “videoconferencing”[TW] AND (“2009/01/01”[PDAT]: “2013/12/31”[PDAT])) NOT editorial[PT]

Table 2 – Top 20 outlets by number of telemedicine related articles (all-time).

Rank (Ties)	Articles	Outlet
1	1823	J Telemed Telecare
2	1147	Telemed J E Health
3	946	Stud Health Technol Inform
4	469	Conf Proc IEEE Eng Med Biol Soc
5	202	Telemed Today ^a
6	184	IEEE Trans Inf Technol Biomed
7	182	Telemed J ^b
8	165	J Med Internet Res
9	162	In J Med Inform
10 (2)	136	BMJ; J Med Syst
11	131	Telemed Virtual Real
12	118	J Digit Imaging
13	108	Health Manag Technol
14	103	Health Data Manag
15	98	Caring
16	97	AMIA Annu Symp Proc
17	89	Healthc Inform
18	76	J Diabetes Sci Technol
19	72	Comput Methods Programs Biomed
20	70	Methods Inf Med
Total	6378	21

^a No longer published.
^b Now published as Telemed J E Health.

3. Results

3.1. Overview of the all-time epoch

The literature search returned 17,932 records for articles published in 2523 unique outlets. The distribution of publications over time in the field is illustrated in Fig. 1. Thirty-eight percent of the articles have been published since 1st January 2010, over half (54%) since 1st January 2006 and over three quarters (76%) since 1st January 2001. It should be noted that not all of these publications relate specifically to the clinical use of telemedicine for rather to the discipline in general. Some papers describe educational and administrative applications together with laboratory studies.

A total of 3152 (18%) papers were published in the specialist telemedicine journals of the JTT (1823 [10%]), TJeH (1147 [6%]) and its predecessor publication *Telemedicine Journal* (182 [1%]). The majority of papers (14,780 [82%]) were published in mainstream outlets. The top 20 ranked outlets (21 outlets including ties) representing 6378 articles, 36% of the total articles for the epoch, are shown in Table 2.

For the all-time epoch, there were 46,066 unique authors. The top 30 ranked authors (a total of 71 authors when including ties) accounted for 2647 articles (Table 5).

3.2. Overview of the early epoch (1970–1995)

For this period, 692 articles (4% of the total telemedicine related literature) were published in 255 unique outlets in this epoch. Of these, 76 (11%) were published in the two

Table 3 – Top 20 outlets by number of telemedicine related articles (early epoch, 1970–1995).

Rank (Ties)	Articles	Outlet
1	40	J Telemed Telecare
2	36	Telemed J
3	31	J Med Syst
4	23	Arch Anat Cytol Pathol
5	18	Proc Annu Symp Comput Appl Med Care
6	16	Medinfo
7 (3)	15	Adm Radiol; Healthc Inf Manage; Healthc Inform
8	14	Health Manag Technol
9 (2)	13	Diagn Imaging (San Franc); Zentralbl Pathol
10	12	Comput Methods Programs Biomed
11 (2)	11	Ann N Y Acad Sci; Health Data Manag
12	10	Mod Healthc
13	8	Acta Astronaut
14	7	AJR Am J Roentgenol
15 (6)	6	CMAJ; Hosp Health Netw; JAMA; Lancet; Stud Health Technol Inform; Tidsskr Nor Laegeforen
16 (6)	5	Br J Gen Pract; BMJ; Canadian Med Assoc J; J AHIMA; Kans Med; Nord Med
17 (5)	4	Caring; Dimens Health Serv; Invest Radiol; Nihon Igaku Hoshasen Gakkai Zasshi; Radiology;
18 (16)	3	Acad Radiol; Am J Emerg Med; Bull Med Libr Assoc; Hawaii Med J; Healthc Forum J; Healthc Syst Strategy Rep; Hosp Technol Ser; Int J Biomed Comput; JEMS; J Image Guid Surg; J Med Assoc Ga; J R Nav Med Serv; Lakartidningen; Prehosp Disaster Med; Radiol Manage; Tex Med Acad Med; Allied Technol; Am J Cardiol; Anal Cell Pathol; Aviat Space Environ Med; Bol Col Prof Enferm P R; Bull Soc Belge Ophtalmol; Bus Health; Calif Hosp; Community Psychiatry; Comput Biol Med; Dent Today; Endosc Surg Hospitals; Eur J Radiol; Health Care Financ Rev; Health Estate J; Health Inf Syst Telemed; Health Syst Rev; Heart Lung; Hosp Rays; Hum Pathol; J Am Geriatr Soc; Soc Sci Med; J Digit Imaging; J Fam Pract; J Healthc Mater Manage; J Natl Cancer Inst; J Radiol; J Rural Health; Mayo Clin Proc; MD Comput; Med Care; Med Group Manage J; Med Inform (Lond); Med J Aust; Minerva Med; Minn Med; NY State Dent J; N Z Health Hospital; OR Manager; Pa Med; Physician Exec; Radiol Med; Radiol Technol; Sygeplejersken; US News World Rep
20	1	Infocare
Total	275	98 unique outlets

specialist journals (JTT, 40 [6%] and *Telemedicine Journal*, 36 [5%]) both of which were launched in 1995. The majority of papers (616, [89%]) were published in non-telemedicine specific journals. The top 20 ranked outlets (a total of 98 outlets including ties) representing 275 articles, 40% of the total articles in the epoch, are shown in Table 3.

Table 4 – Top 20 outlets by number of telemedicine related articles (contemporary epoch, 2009 – 2013).

Rank (Ties)	Articles	Outlet
1	585	Telemed J E Health
2	367	J Telemed Telecare
3	308	Stud Health Technol Inform
4	224	Conf Proc IEEE Eng Med Biol Soc
5	130	J Med Internet Res
6	59	J Med Syst
7 (2)	56	IEEE Trans Inf Technol Biomed; J Diabetes Sci Technol
8 (2)	48	BMJ; Int J Med Inform
9	38	Health Serv J
10	35	Europace
11	32	Stroke
12 (2)	31	Biomed Instrum Technol; Int J Telemed Appl
13	30	Psychol Serv
14 (2)	29	J Digit Imaging; Rural Remote Health
15	28	PLoS ONE
16 (2)	27	Diagn Radiol; Health Aff (Millwood)
17 (3)	25	Caring; Health Manag Technol; IEEE Trans Biomed Eng
18 (4)	23	Diabetes Technol Ther; J Am Coll Radiol; Med J Aust; Sensors (Basel)
19	22	J Am Acad Dermatol
20	21	BMC Health Serv Res
Total	2118	30 unique outlets

The early epoch contained 1385 unique authors. The top ranked authors (a total of 8 authors when including ties) accounted for 55 articles (Table 6).

3.3. Overview of the contemporary epoch (2009–2013)

In this epoch, 6383 articles (36% of the total telemedicine related literature) were published in 1460 unique outlets. Of these, 952 (15%) were published in the two specialist journals (JTT, 367 [6%] and TJeH, 585 [9%]). As in the cumulative view, the majority of papers (5431 [85%]) were published in other non-telemedicine specific journals. The top 20 ranked outlets (a total of 30 outlets including ties) representing 2118 articles, 33% of the total articles in the epoch, are shown in Table 4.

The contemporary epoch contained 21,109 unique authors. Table 7 shows the 65 ranked authors with 10 or more articles (including editorials). These authors accounted for 1068 articles. Table 8 shows the ranking of authors after exclusion of editorials. Sixty two unique authors are listed, representing 944 articles. Excluding editorials markedly changed the ranking of the top two authors in this epoch (Doarn and Merrell) from first and second place to equal 9th and equal 14th respectively. This is explained by these authors being editors, and regular editorial writers, for the TJeH. A similar decrease in ranking was not observed for the editor of the JTT (Wootton) who increased from 3rd place to 1st place once editorials had been excluded.

Table 5 – Top 30 author list, ranked by total number of publications (all-time).

Rank (Ties)	Author	Number of articles
1	Wootton, Richard	162
2	Merrell, Ronald	138
3	Doarn, Charles	133
4	Demiris, George	75
5	Krupinski, Elizabeth	73
6	Whitten, Pamela	64
7	Weinstein, Ronald	63
8	Smith, Anthony C	59
9	Yellowlees, Peter	54
10	Soyer, H Peter	46
11	Tachakra, Sapal	44
12 (2)	Scalvini, Simonetta; Starren, Justin	42
13 (2)	Russell, Trevor; Shea, Steven	41
14 (2)	Nesbitt, Thomas; Weinstock, Ruth	40
15	Mair, Frances	39
16 (2)	Hailey, David; Scott, Richard	37
17 (2)	May, Carl; Patterson, Victor	36
18	Kvedar, Joseph	35
19 (2)	Della Mea, Vincenzo; Demaerschalk, Bart;	34
20 (3)	Allen, Ace; Audebert, Heinrich; Istepanian, Robert	32
21 (4)	Bashshur, Rashid; Giansanti, Daniele; Kayser, Klaus; Sheikh, Aziz;	31
22 (2)	Hilty, Donald; Jennett, Penny	30
23 (4)	Doolittle, Gary; Grigsby, Jim; Kavoussi, Louis; Shore, Jay	29
24	Siwicki Bill	28
25 (4)	Clarke, Malcolm; Finkelstein, Joseph; Gagnon, Marie-Pierre; Mars, Maurice	27
26 (6)	Gomez, Enrique; Ferguson, James; Finkelstein, Stanley; Giordano, Amerigo; Vollenbroek-Hutten, Miriam; Theodoros, Deborah	26
27 (7)	Armfield, Nigel; Arredondo Maria Teresa; Chumbler, Neale; Hofmann-Wellenhof, Rainer; Kobb, Rita; Lopez, Ana Maria; Yogesana, Kanagasigam	25
28 (6)	Bellazzi, Riccardo; Garcia, Jose; Kinsella, Audrey; Maglaveras, Nicos; Marcin, James; Yoo, Sun	24
29 (3)	Latifi, Rifat; Ohinmaa, Arto; Lovell, Nigel	23
30 (6)	Blobel, Bernd; Bosworth, Hayden; Glisenti, Fulvio; Koutsouris, Dimitrios; Palmas, Walter; Izquierdo, Roberto	21
Total	71 unique authors	2647

3.4. Content analysis of abstracts

The process of illustrating key words according to publication frequency helps to identify themes and emerging topics. Fig. 2 shows the tag clouds of articles published in the early and contemporary epochs.

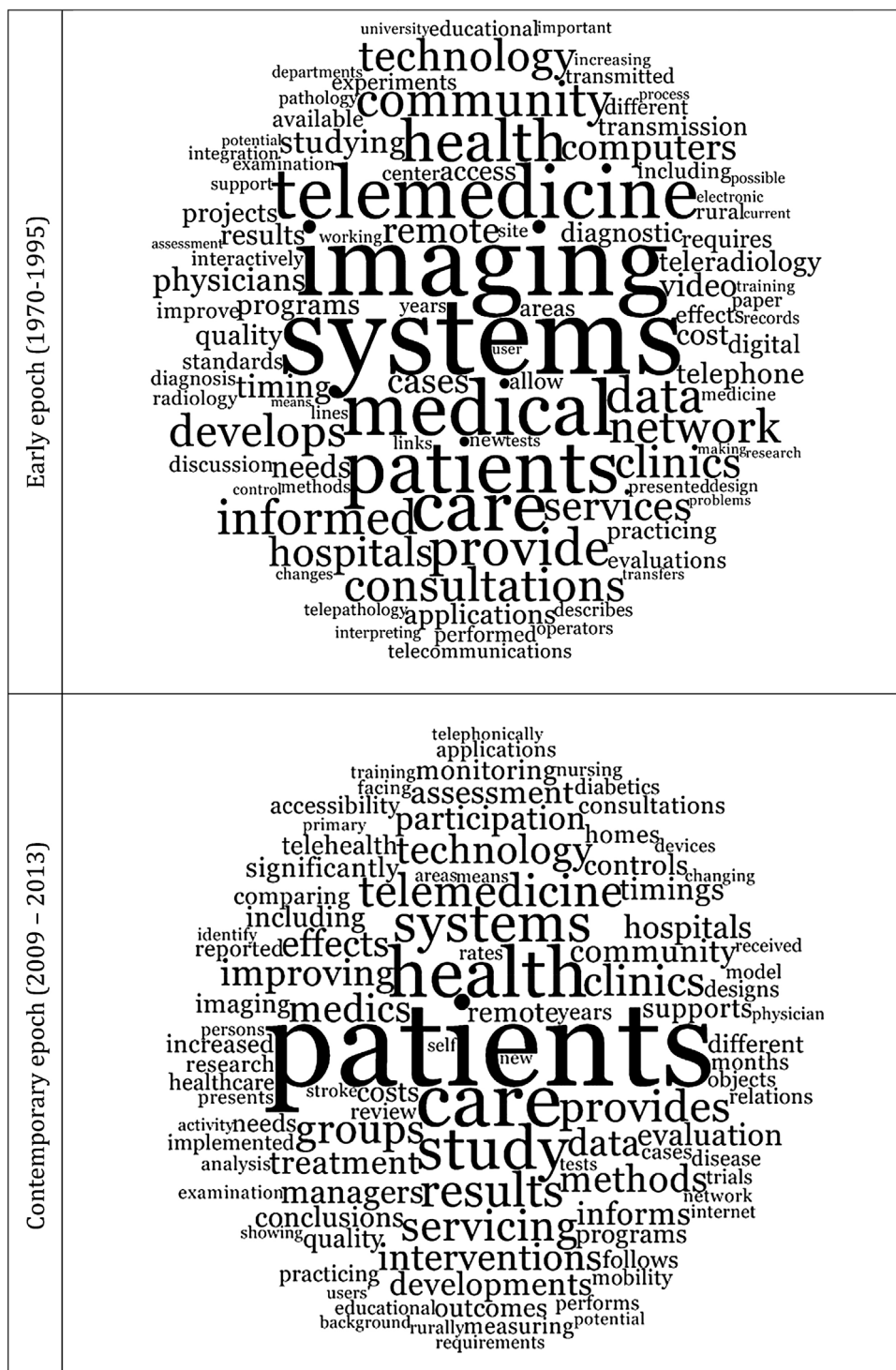


Fig. 2 – Tag clouds of words appearing in article abstracts for early and contemporary epochs.

4. Discussion

We took a new bibliometric approach to describing the telemedicine related literature, combining information about authors, outlets and content. In doing so, we have provided a broad overview of publication trends over time.

Examining topics during the early adoption of telemedicine and comparing them with recent published reports, gives valuable insight into the maturity, scope and perception of telemedicine. Interestingly, our study has shown that telemedicine has evolved from a heavily technical domain to one with a more patient-centric and clinical focus.

Table 6 – Author list, ranked by total number of publications for authors with five or more publications (early epoch, 1970–1995).

Rank (Ties)	Author	Number of articles
1 (2)	Bashshur, Rashid; Allen, Ace	10
2 (2)	Cannavo, Michael; Kayser, Klaus;	7
4	Franken, Edmund	6
5 (3)	Ball, Chris; Dusserre, Pierre; Nordrum, Ivar	5
Total	8 unique authors	55

Table 7 – Author list, ranked by total number of publications for authors who have contributed to at least ten articles (contemporary epoch, 2009–2013).

Rank (Ties)	Author	Number of articles
1	Doarn, Charles	55
2	Merrell, Ronald	50
3	Wootton, Richard	36
4 (2)	Demaerschalk Bart; Demiris, George	31
5	Smith, Anthony	29
6	Krupinski, Elizabeth	26
7 (2)	Mars, Maurice; Russell, Trevor	22
8 (3)	Bosworth, Hayden; Sheikh, Aziz; Weinstock, Ruth	20
9 (2)	Kovarik, Carrie; Weinstein, Ronald	19
10	Armfield, Nigel	18
11 (5)	Audebert, Heinrich; Scalvini, Simonetta; Shea, Steven; Soyer, H Peter; Theodoros, Deborah	17
12 (4)	Boedeker, Ben; Christensen, Helen; Shore, Jay; Wittenberg-Lyles, Elaine	16
13 (4)	Gray, Leonard; Parker Oliver, Debra; Sabesan, Sabe; Titov, Nickolai	15
14 (6)	Finkelstein, Joseph; Giansanti, Daniele; Izquierdo, Roberto; McKinstry, Brian; Teresi, Jeanne; Vollenbroek-Hutten, Miriam	14
15 (8)	Andersson, Gerhard; Eimicke, Joseph; Garcia, Jose; Geissbuhler, Antoine; Rogers, Anne; Scott, Richard; Starren, Justin; Varma, Niraj	13
16 (5)	Armstrong, April; Kroenke, Kurt; Marcin, James; Nesbitt, Thomas; Ozcan, Aydogan	12
17 (13)	Andrews Gavin; Cafazzo, Joseph; Cuijpers, Pim; Fraga, Gustavo; Gagnon, Marie-Pierre; Koehler, Friedrich; Meyer, Brett; Pagliari, Claudia; Palmas, Walter; Ricci, Renato; Schreier Gunter; Wu, Jingwei; Zanaboni, Paolo	11
18 (5)	Blobel, Bernd; Lopez, Ana Maria; Pare, Guy; Switzer, Jeffrey; Tu, Wanzhu	10
Total	65 unique authors	1068

Table 8 – Author list, ranked by total number of publications for authors who have contributed to at least ten articles (contemporary epoch, 2009–2013, excluding editorials).

Rank (Ties)	Author	Number of articles
1	Wootton, Richard	36
2	Demiris, George	31
3	Demaerschalk Bart	30
4	Smith, Anthony	29
5	Krupinski, Elizabeth	25
6 (2)	Mars, Maurice; Russell, Trevor	21
7 (2)	Bosworth, Hayden; Weinstock, Ruth	20
8 (2)	Kovarik, Carrie; Sheikh, Aziz	19
9 (3)	Armfield, Nigel; Doarn, Charles; Weinstein Ronald	18
10 (3)	Shea, Steven; Soyer, H Peter; Theodoros, Deborah	17
11 (5)	Audebert, Heinrich; Boedeker, Ben; Scalvini, Simonetta; Shore, Jay; Wittenberg-Lyles, Elaine	16
12 (5)	Christensen, Helen; Gray, Leonard; Parker Oliver, Debra; Sabesan, Sabe; Titov, Nickolai	15
13 (6)	Finkelstein, Joseph; Giansanti, Daniele; Izquierdo, Roberto; McKinstry, Brian; Teresi Jeanne; Vollenbroek-Hutten, Miriam	14
14 (6)	Eimicke, Joseph; Garcia, Jose; Merrell, Ronald; Rogers, Anne; Scott, Richard; Starren, Justin;	13
15 (5)	Armstrong, April; Geissbuhler, Antoine; Nesbitt, Thomas; Ozcan, Aydogan; Varma, Niraj	12
16 (11)	Andersson, Gerhard; Andrews, Gavin; Gagnon, Marie-Pierre; Koehler, Friedrich; Kroenke, Kurt; Marcin, James; Pagliari, Claudia; Palmas, Walter; Schreier, Gunter; Wu, Jingwei; Zanaboni, Paolo	11
17 (7)	Cafazzo, Joseph; Cuijpers, Pim; Fraga, Gustavo; Meyer, Brett; Pare, Guy; Ricci, Renato; Tu, Wanzhu;	10
Total	62 unique authors	944

4.1. Outlets and authors

In all three of the epochs, more than 80% of articles were published outside of the specialist telemedicine journals. However, the extent to which articles have reached a general clinical audience is unclear, since few clinical journals were strongly represented in the top 20 outlets, though this is perhaps changing: In the contemporary epoch, the general journals *BMJ*, *Stroke*, *Rural and Remote Health*, *PLoS ONE*, *Caring* and the *Medical Journal of Australia* are all represented and account for a total of 185 articles. Health services journals such as *Health Services Journal* and *BMC Health Services Research* together with the health policy journal *Health Affairs* are represented in the top 20.

Because the number of authors contributing to the field in the early epoch was small, it is possible to examine their

contributions closely. From 1976, Bashshur was the earliest in the field to discuss definitions, challenges and the evaluation of telemedicine [10–19]. Some of these challenges, such as liability, credentialing, reimbursement and influencing health policy are still familiar to telemedicine practitioners and researchers today. Commencing in 1992, Allen provided the earliest reports from an established telemedicine program [20]. He reported on patient satisfaction, physician acceptance, protocols and standards and the organization and communication hindrances to telemedicine [20–28]. Again, these are themes that are still of concern in the literature today. Telepathology and teleradiology are anecdotally considered the oldest applications of telemedicine. This is confirmed with the articles on telepathology of Nordrum [29–33], Kayser [34–40] and Dusserre [41–45] from 1992, together with teleradiology articles by Franken in also 1992 [25,46,47] and by Cannavo from 1993 [48–54]. In 1992, Ball began publishing on telepsychiatry [55–58], now one of the largest applications of telemedicine. In 1995 Ball was perhaps the first author to declare that despite technological advances, evaluation has failed to show advantages and that new methods for evaluating its benefit to patient care were needed [59].

Because the field is now very large, a granular examination of the contributions of authors for the all-time and contemporary epochs was beyond the scope of this study. Rather, we relied on general thematic comparison.

4.2. Themes in the early epoch

Terms used in the abstracts of articles in the early epoch were characterized by their technical nature with terms such as “systems”, “imaging”, “data” and “computers” appeared prominently in the tag cloud. As an embryonic field, it is plausible that the emphasis of the early literature was mostly on technical matters, or that the investigators had a primarily technical interest. Work in pathology and radiology, previously highlighted as two of the first medical disciplines to adopt telemedicine, was reflected in the tag cloud as “telepathology” and “teleradiology”. These are the only discipline-related terms to appear.

4.3. Themes in the contemporary epoch

In the contemporary epoch, terms relating to use of clinical use of telemedicine such as “patients”, “health” and “care” appear more prominently. While the tag cloud features references to systems and technology related words, these terms are less prominent. Clinical and discipline specific terms such as “diabetic” and “stroke” and “mobility” emerged in the contemporary epoch.

4.4. Differences in themes between the early and contemporary epochs

The two tag clouds are markedly different. In the contemporary period, clinical care phrases are much more prominent than the technology-related terms. This suggests that the emphasis on technology within the literature

has decreased and that the focus has changed to the clinical applications of telemedicine. This may be indicative that the technical challenges have been overcome by improvements in readily available technology, or perhaps the realization that successful telemedicine requires the consideration of non-technical as well as technical factors.

In the earlier epoch, the term “imaging” was frequently used, most likely to describe the telemedicine applications involving transmission of radiological images. Since teleradiology has now become mainstream, this may explain the absence of the term in the contemporary epoch.

Terms related to research and evaluation such as “analysis”, “measuring”, “outcomes” and “trials”, while present in both clouds, appear to be more prominent in the tag cloud for the contemporary epoch.

The term “homes” appears in the contemporary epoch only and “monitors” is more prominent in the contemporary epoch than “monitoring” in the early epoch. This may be attributed to the growth of the Internet and the increasing interest and potential feasibility of using telemedicine to provide health services into the home setting.

4.5. Similarities in themes between the early and contemporary epochs

Both epochs identify patients as a core theme, which supports a key purpose of telemedicine, which is to provide people with access to health care at a distance.

Terms relating to economics (e.g. costs) appear in both epochs but not with prominence in either, perhaps suggesting that formal economic analyses in the field are not yet prevalent. This is consistent with reports in the literature of the lack of good quality economic evidence to support the use of telemedicine [60]. This is an important point, because as the costs associated with health care are increasingly rationalized, there is increased need to conduct economic analyses of telemedicine to inform health service managers and policy makers of the potential costs and savings associated with telemedicine [61].

4.6. Limitations

This study had some limitations: firstly, while the search strategy was broad, it was informal, automated and relied on a single data source (MEDLINE via PubMed). This means our summary may not necessarily be representative of the literature as a whole. However, this source is the most comprehensive index of peer reviewed medical literature available to us that allowed open programmatic access.

Secondly, in identifying publications by epoch, we used the PDAT restriction term in our queries. However, the date when MeSH headings are applied (MHDA) may be months later than the publication date. Therefore some articles published late in an epoch may have been missed; for example if an article was published late in 2013, with an MHDA in 2014, then it may have been missed from the contemporary and all-time epoch analysis. However, the number of

articles missed is likely to be small and hence only have a minor bearing on the overall summary reported in this paper.

Finally, we used a manual combining and checking process for the author rankings. While the process was thorough and was double checked, because of the size of the data set it is possible that some combinations were missed.

Despite these limitations, we have demonstrated that this approach can be used to produce an overview of publication trends and the content of the body of literature.

5. Conclusion

This study provides new information on the nature of publication in the field of telemedicine and telehealth and updates the findings of previous studies. Publication in the field has been strong in the past few years with a diverse range of outlets publishing telemedicine related articles. From our summary analysis, the emphasis within the literature appears to have moved from technical related issues to clinical applications and evaluation. The home, as a healthcare setting appears to also be gaining coverage.

Some questions remain – in particular, the maturity of the field and its effectiveness in reaching clinicians and policy makers with useful evidence is unclear and requires further exploration. Some of the problems hindering the growth of telemedicine which were identified by the pioneers, such as reimbursement and economics still remain problems today.

Author's contribution

NRA conceived the study, led its design, developed the software tools, used the software tools to access and process the MEDLINE records. He contributed to analysis, drafting and revision of the manuscript. SE contributed to drafting of the manuscript. LJC contributed to content analysis, results interpretation and drafting of the manuscript. NB contributed to the design of the study. NB and JG, performed the content analyses in Nvivo, interpreted the results and contributed to drafting and revision of the manuscript. ACS contributed to drafting and revision of the manuscript. All authors approved the final manuscript.

Conflict of interest statement

The authors have no conflicting interests to declare. The study was conducted as internal unfunded research

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Summary points

What was known on the topic

- While previous studies have examined the telemedicine-related literature, none have been conducted in recent years and hence the contemporary situation was unknown.
- No studies have examined trends in the content of the telemedicine-related literature and it was not known whether the emphasis was changing over time.

What this study has added to our knowledge

- Publication of articles in the telemedicine field is strong.
- Over 80% of telemedicine related articles were published in non-telemedicine specific journals.
- Early publications in the field were focused largely on technical matters. In recent times, this focus has changed to clinical applications and evaluation. Further work is needed to explore whether this is an indication of a maturing field.
- However, reach to clinicians and policy makers is questionable since few clinical or policy journals appear to have published many papers.

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