

Cervix elastography: a bibliometric analysis

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Summary

Introduction: The aim of this study was to assess the global contribution to cervical elastography research in PubMed, Scopus, and Web of Science databases. **Materials and Methods:** PubMed, Scopus, and Web of Science databases were queried without language restrictions for records present up to January 2016. All indexed publications under cervix elastography were retrieved. All meta-informations present in the databases were locally stored and used for the analyses. **Results:** The absolute number of publications included was 107. The top four countries to publish on the argument were USA (23 publications), UK (16 publications), Germany (5), and Poland (5). Finally the most researched areas were cervical ripening in labor induction, pre-term delivery prediction, and cervical cancer analysis. **Conclusions:** Although interest in this field has greatly increased in recent years, original articles on this topic are still limited.

Key words: Elastography; Cervix uteri; Diagnostic techniques; Prenatal ultrasonography; Pregnancy.

Introduction

Ultrasound technology has dramatically improved in the recent years, having as its main goal the highest possible objectification of any target medical feature especially in the field of gynecology and obstetrics [1–4]. Indeed, we know that the ability to measure a phenomenon is the primary requirement for promoting scientific medical progress. Elastography is a new tool for imaging and estimation of tissue elasticity by ultrasound imaging [5]. It tracks tissue movement, obtaining an estimate of tissue stiffness [6]. Some pioneering studies have demonstrated its feasibility in studying tissue elasticity, also in differentiation of cancer tissues from normal tissues [7, 8]. Two main approaches have been proposed for elastography, based on different methods and technology used. These are the strain elastography, based on the examination of the deformation (strain) of a tissue due to application of a force, and the shear wave elastography, based on the determination of the propagation speed of shear waves through the tissue [9–14].

Recently, the application of this new ultrasound tool for the study of the uterine cervix, both in gynecology, as well as in obstetrics [15–17] has been proposed. Particularly interesting is the study of cervical stiffness during pregnancy. Even though only few studies have addressed this topic, confirming its possible use in evaluating uterine cervical maturation in the prediction of preterm delivery, or labor induction success [4, 5, 18], literature is increasing in this field.

To date, bibliometric studies concerning the quantity and

quality of articles published on cervical elastography during pregnancy are missing. This study aims to assess the global contribution to cervical elastometry research in PubMed, Scopus, and Web of Science.

Materials and Methods

This bibliometric study was performed on data retrieved from PubMed, Scopus, and Web of Science databases without language restrictions for publication recorded up to January 2016.

The research strategy in PubMed was the following: ‘(“cervix uteri”[MeSH Terms] OR (“cervix”[All Fields] AND “uteri”[All Fields]) OR “cervix uteri”[All Fields] OR “cervix”[All Fields]) AND (“elasticity imaging techniques”[MeSH Terms] OR (“elasticity”[All Fields] AND “imaging”[All Fields] AND “techniques”[All Fields]) OR “elasticity imaging techniques”[All Fields] OR “elastography”[All Fields])’. In the Scopus database the research strategy was: “TITLE-ABS-KEY (cervix elastography)”. In the Web of Science database the research strategy was: cervix elastography.

All retrieved information was stored as comma separated value data sets, bibtext format, or PubMed format. The journal impact factor referred to the 2014 journal citations report. Geolocalization of contributions was estimated by affiliation field in the downloaded meta-information.

All the retrieved articles were evaluated by the following aspects: author list, corresponding author, language, document type, journal, year of publication, and number of citations. All manuscripts reporting human experimentation results were assessed to be compliant with World Medical Association Declaration of Helsinki (local institutional review board approval and informed consent). Moreover, the top ten frequently cited articles about cervical elastography were discussed. In addition, all retrieved authors were considered for total citations and H-index specific for

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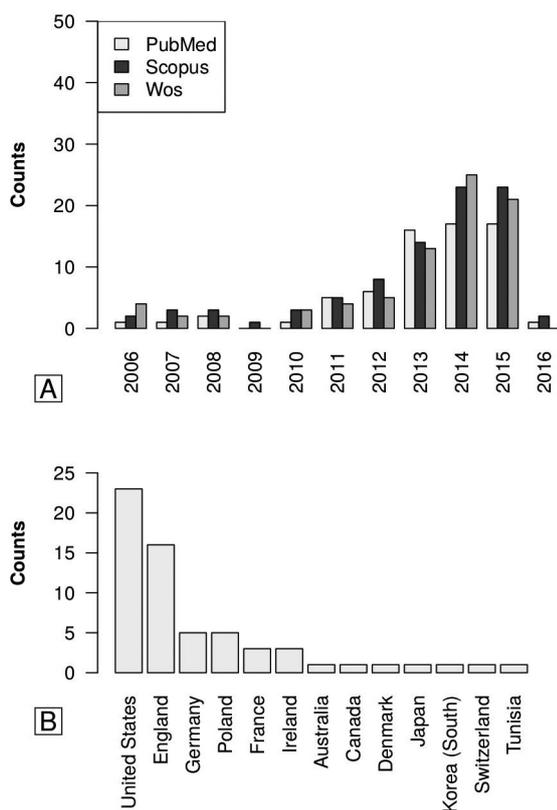


Figure 1. — (Panel A) Frequencies of publications by year subdivided by PubMed and Scopus. (Panel B) Publication frequencies by country of origin (PubMed data).

the retrieved articles in cervix elastography (according to Scopus or the Web of Science database).

Statistical analysis was performed using the program R (version 3.1.2 - <http://www.R-project.org/>). Data are presented as frequencies or percentages. Furthermore, specific H-index was calculated and word clouds were drawn for PubMed Mesh words and PubMed abstracts words.

Results

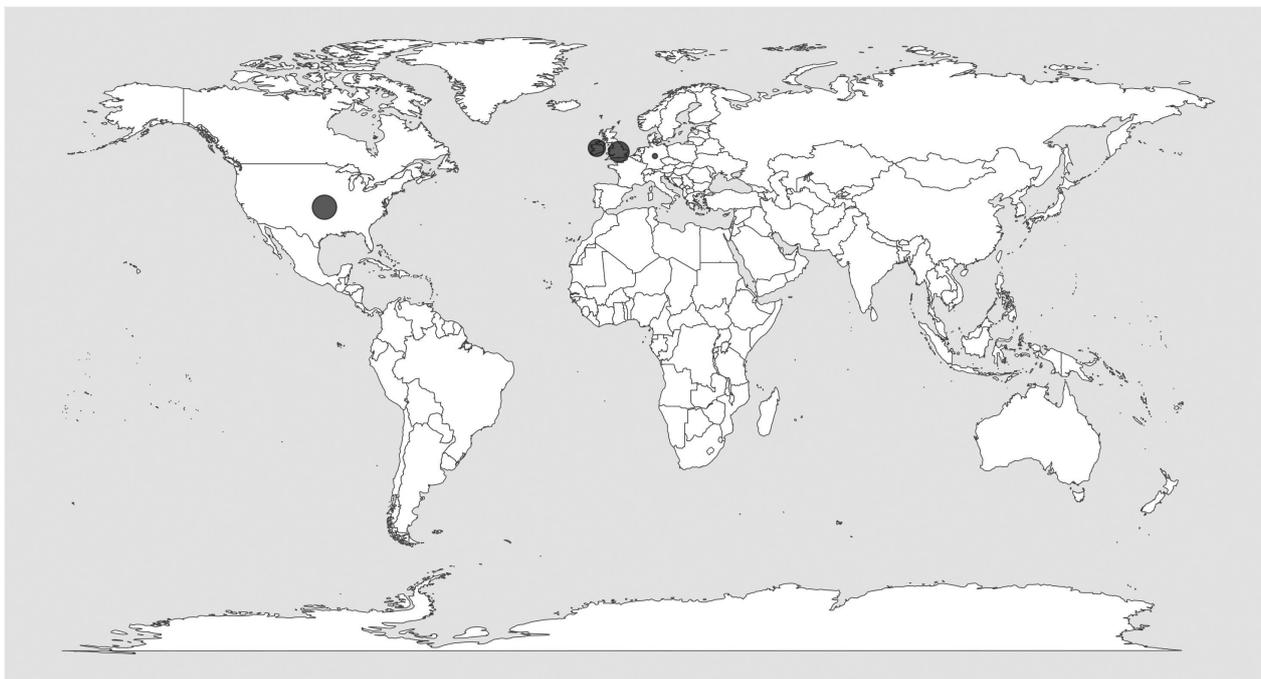
The PubMed database returned 69 items, the Scopus database returned 88 items (31 of which were not present in the PubMed query), and Web of Science returned 79 items (18 of which were not present in the PubMed or Scopus queries). The total amount of retrieved items was 113. Three items were excluded because they were not related to cervical elastography; thus the total amount of included abstracts in the analyses was 110 (67 in the PubMed query, 85 in the Scopus query, and 78 in Web of Science query). Figure 1A shows an increase of publication frequencies from the year 2010 in Scopus and Web of Science, and 2011 in PubMed. In Figure 1B it was found that the top countries to work on this argument were the United States of America, the United Kingdom, Germany, and Poland (these coun-

tries contributed to 79.1% of publications found in PubMed, in five cases the country field was not specified). 91.0% (61/67) of articles were in English, 6.0% in French, and a minority were in German and Polish (PubMed data). Considering the type of articles as recorded in Scopus 72.9% (62/85) of items were marked as “Article” and 2.4% (2) as “Article in Press”, 11.8% (10) were reviews, 9.5% (8) were letters, editorials or opinion papers, and 3.5% (3) were conference papers. Considering the type of articles as recorded in PubMed 76.12% (51/67) were journal articles, 13.43% (9/67) reviews, and 10.45% (7/67) letters or comments. 19.4% of articles resulted were funded by US government (two cases were funded by intramural and extramural NIH grants) and 80% of these were extramural research grants (investigators throughout the US and abroad). 19.4% of work (13/67) were funded by non US government sources (articles noted as supported by other American sources or by foreign sources). In addition, in the US, 56.5% (13/23) of articles were granted by government and 21.7% (5/23) by other American sources (societies, institutes, state governments, universities, private organizations, etc.). Only two articles were contemporary, funded by NIH and other American sources (thus 69.6% of US studies were funded by NIH or other American sources). In Figure 2 a world map of the non-US government funded published articles as registered in PubMed is shown and five of the 13 projects are located in the US followed by the UK, Ireland, and Germany with only one published study.

The institution with the highest frequency of affiliations in PubMed was the University of Wisconsin-Madison with six records, followed by Mathias-Spital Rheine with five records, Aarhus University and the University of Granada with four records, and a group of institutions with two records (Charité-Universitätsmedizin Berlin, the Medical University of Lublin, the University of Colorado, the University of Gdansk, and Wroclaw Medical University). Table 1 shows the most productive authors in the field as found in PubMed and in Table 2 the most cited authors as found in the Scopus or Web of Science databases. Considering the Scopus database, the most cited authors are pioneers in the field: Garra B.S. and Thomas A. who published 5-6 years before the main-stream of the argument. They published only a limited number of articles on this argument, therefore the H-index specific for this argument is low (Table 2A). In fact, in Table 2A the top authors of this specific Scopus query are also reported. Table 2B indicates the most cited authors and the authors with the highest H-index (specific for this query) in the Web of Science database. Table 2A and 2B are overlapped for most of the listed names.

Table 3 gives the top ten cited articles in Scopus, while in Table 4 the top ten cited articles in the Web of Science. The two lists are mostly overlapped and the main argument is pregnancy. Furthermore, the majority of listed items are original articles.

Focus was then placed on the research hotspots in cervix



Country	United States	England	Ireland	Germany	Australia	Canada	Denmark	France	Japan	Korea (South)	Poland	Switzerland	Tunisia
Frequency	5	4	3	1	0	0	0	0	0	0	0	0	0

Figure 2. — World map of studies indexed in PubMed as having non-US government research support.

Table 1. — The most productive authors in the field (PubMed data).

Top first authors (>1 article)	Frequency	Top senior authors (>1 article)	Frequency	Top authors (>3 article)	Frequency
Fruscalzo A	7	Schmitz R	7	Fruscalzo A	9
Hee L	4	Uldbjerg N	4	Schmitz R	9
Hernandez-Andrade E	4	Hall TJ	3	Hall TJ	5
Peralta L	4	Paszowski T	3	Londero AP	5
Fuchs T	3	Romero R	3	Ahn H	4
Swiatkowska-Freund M	3	Zimmer M	3	Chaiworapongsa T	4
Feltovich H	2	Hartenbach EM	2	Feltovich H	4
Wozniak S	2	Molina FS	2	Hassan SS	4
		Nicolaides KH	2	Hee L	4
		Preis K	2	Hernandez-Andrade E	4
				Korzeniewski SJ	4
				Molina FS	4
				Peralta L	4
				Preis K	4
				Romero R	4
				Swiatkowska-Freund M	4
				Uldbjerg N	4
				Varghese T	4
				Yeo L	4

Table 2. — The most cited authors in the field (A= Scopus data and B= Web of Science data).

Top cited authors (>50)	Number of citations	Top H-index (>2)	H-index (*)
(A) Scopus			
Garra BS	142	Fruscalzo A	5
Thomas A	110	Schmitz R	5
Hall TJ	94	Feltovich H	4
Feltovich H	88	Frohlich C	4
Fischer T	87	Hall TJ	4
Gemeinhardt O	87	Londero AP	4
Kummel S	87	Preis K	4
Preis K	82	SwiatkowskaFreund M	4
SwiatkowskaFreund M	82	Ahn H	3
Fruscalzo A	77	Chaiworapongsa T	3
Schmitz R	77	Hassan SS	3
Nicolaides KH	69	HernandezAndrade E	3
Molina FS	58	Klockenbusch W	3
Florido J	56	Korzeniewski SJ	3
Gomez LF	56	Romero R	3
Padilla MC	56	Thomas A	3
		Uldbjerg N	3
		Yeo L	3
(B) Web of Science			
Thomas A	85	Fruscalzo A	5
Fischer T	83	Schmitz R	5
Gemeinhardt O	82	Preis K	4
Kuemmel S	82	Swiatkowska-Freund M	4
Preis K	79	Ahn H	3
Swiatkowska-Freund M	79	Chaiworapongsa T	3
Mazza E	70	Feltovich H	3
Nicolaides KH	68	Hall TJ	3
Bajka M	67	Hassan SS	3
Molina FS	57	Hernandez-Andrade E	3
Bauer M	56	Klockenbusch W	3
Florido J	56	Korzeniewski SJ	3
Gomez LF	56	Mazza E	3
Holzapfel GA	56	Romero R	3
Nava A	56	Uldbjerg N	3
Padilla MC	56	Varghese T	3
Winter R	56	Yeo L	3
Fruscalzo A	51		
Schmitz R	51		

(*) H-index calculation takes in consideration only articles about cervical elastography.

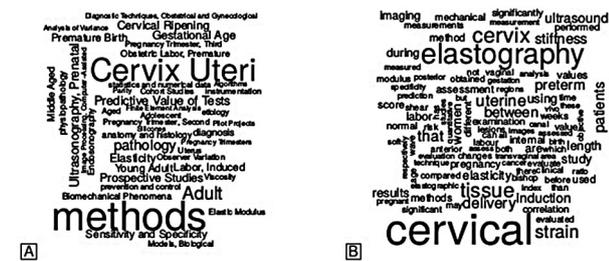


Figure 3. — (Panel A) Word cloud plot of MeSH terms. (Panel B) Word cloud plot of abstract words.

elastography. PubMed MeSH terms were analysed and 176 MeSH terms appeared 858 times (93 MeSH terms appeared only once and other 30 two times). Not all of the PubMed abstracts were included in this analysis because 16 abstracts (23.2%) were short of MeSH terms. Figure 3A shows the word cloud plot of MeSH terms. The analysis of MeSH terms shows that the main focus of research was predictability of preterm birth and cervical ripening. Figure 3B indicates the analysis of the words of all included abstracts (the word cloud shows the most 100 frequent words). In 13 cases the abstract was not present in the considered databases; therefore 93 abstracts were included for analysis. The abstracts included 2,887 words used 13,129 times. The 100 most frequent words were used 4,852 times and these

Table 3. — *The top ten cited articles in the field (Scopus data).*

Title	Type of article	Journal	First author/institute	Year	Times cited
Imaging and estimation of tissue elasticity by ultrasound	Review	Ultrasound Quarterly	Garra BS / Fletcher Allen Health Care, Burlington	2007	142
Real-Time sonoelastography of the cervix: tissue elasticity of the normal and abnormal cervix	Article	Acad Radiol	Thomas A / Charité, University of Berlin	2007	87
Elastography of the uterine cervix: implications for success of induction of labor	Article	Ultrasound Obstet Gynecol	Swiatkowska-Freund M / University of Gdansk	2011	57
Quantification of cervical elastography: a reproducibility study	Article	Ultrasound Obstet Gynecol	Molina FS / San Cecilio University Hospital, Granada	2012	56
Beyond cervical length: emerging technologies for assessing the pregnant cervix	Review	Am J Obstet Gynecol	Feltovich H / Intermountain Healthcare, Provo	2012	42
Evaluation of cervical stiffness during pregnancy using semiquantitative ultrasound elastography	Article	Ultrasound Obstet Gynecol	Hernandez-Andrade E / NICHD / NIH / DHHS, Bethesda	2013	39
Frequency-dependent complex modulus of the uterus: preliminary results	Article	Phys Med Biol	Kiss MZ / University of Wisconsin-Madison	2006	31
Musculoskeletal applications of elastography: a pictorial essay of our initial experience	Article	Korean J Radiol	Lalitha P / Focus Diagnostic Center, Punjagutta	2011	28
Quantitative imaging of the cervix: setting the bar	Note	Ultrasound Obstet Gynecol	Feltovich H / University of Wisconsin-Madison	2013	23
Reliability of cervix elastography in the late first and second trimester of pregnancy	Article	Ultraschall Med	Fruscalzo A/Mathias-Spital Rheine	2012	21

Table 4. — *The top ten cited articles in the field (Web of Science data).*

Title	Type of article	Journal	First author/institute	Year	Times cited
Real-time sonoelastography of the cervix: tissue elasticity of the normal and abnormal cervix	Article	Acad Radiol	Thomas A / Charité, University of Berlin	2007	82
Mechanical properties of the human uterine cervix: an in vivo study	Article	Medical Image Analysis	Mazza E / Swiss Federal Institute of Technology, Zurich	2006	56
Quantification of cervical elastography: a reproducibility study	Article	Ultrasound Obstet Gynecol	Molina FS / San Cecilio University Hospital, Granada	2012	56
Elastography of the uterine cervix: implications for success of induction of labor	Article	Ultrasound Obstet Gynecol	Swiatkowska-Freund M / University of Gdansk	2011	56
Evaluation of cervical stiffness during pregnancy using semiquantitative ultrasound elastography	Article	Ultrasound Obstet Gynecol	Hernandez-Andrade E / NICHD / NIH / DHHS, Bethesda	2013	38
The cervix as a biomechanical structure	Editorial	Ultrasound Obstet Gynecol	House M / Tufts-New England Medical Center, Boston	2006	30
Frequency-dependent complex modulus of the uterus: preliminary results	Article	Phys Med Biol	Kiss MZ / University of Wisconsin-Madison	2006	28
Quantitative imaging of the cervix: setting the bar	Note	Ultrasound Obstet Gynecol	Feltovich H / University of Wisconsin-Madison	2013	23
Musculoskeletal applications of elastography: a pictorial essay of our initial experience	Article	Korean J Radiol	Lalitha P / Focus Diagnostic Center, Punjagutta	2011	21
Our initial experience quantitative cervical elastography in pregnancy	Letter	Ultrasound Obstet Gynecol	Fruscalzo A / St. Franziskus Hospital, Muenster	2012	20

words are plotted in Figure 3B. This analysis produced another argument treated in this field, therefore the main topics are: cervical ripening in labor induction, pre-term delivery prediction, and cervical cancer analysis.

Discussion

Elastography has shown considerable progress in recent years. In particular, the introduction of the new tool in the assessment of cervical stiffness has opened a new field of research, both in gynecology and obstetrics. Bibliometric studies have been used in many biomedical fields to evaluate worldwide research productivity. Indeed, tracing the new mainstreams on medical topics has assumed a rising relevance for research institutions and companies that need to be up-to-date and aspire to lead future developments. In this bibliometric analysis the authors showed how the number of publications has increased in the last years, the most participating countries, institutions and researchers, as well as the most published topics considered.

Scientific productivity generally correlates with the speed of progress in science and technology and a sharp improvement in the number of publications likely indicates the presence of a relevant breakthrough in that discipline. The present results show how the number of publications dealing with cervical elastography steadily augmented after the first publications in the year 2006, until 2016, indicating a progressive interest in this medical topic. Interestingly, the publication of the first paper on this topic [15] preceded by a few years, the publication of the first clinical studies, started after 2011 [19]. In the meanwhile, elastography as an ultrasound tool for cervical stiffness assessment remained almost neglected. This phenomenon is called “The sleeping beauty” [20]. It can be explained as the gap that has to be filled after a breakthrough has been introduced, to further the dissemination of this acknowledgement. An increase in the number of papers produced in this area of research is expected in the future with widespread use of this technology, provided that the usefulness of this tool in clinical practice is confirmed by future research.

Most papers are original articles (72.9%), published in English (91.0%), suggesting the presence of a wide target of readers. The United States of America, the United Kingdom, Germany, and Poland contributed to the major portion of scientific publications (79.1%). The geographic distribution is of interest, generally reflecting the technological and research capabilities of different countries. Nonetheless, this was also strongly related to the location of the institutions where the study was conducted, as there were a relatively small number of research groups involved. This can be extrapolated from the results of the most productive authors in this field. This indicates that this technology is not currently widespread and is still in an experimental phase.

Of note is the fact that the majority of the studies were conducted without US or non-US funding. This suggests that the capabilities needed in this context are not all de-

pendent on the amount of financial support received. Elastography technology and software were developed in the late nineties to be applied in other fields of medicine, among others liver, prostate, breast, and thyroid diseases [21–24]. This tool is currently routinely included in high-end ultrasound machinery, even though the type of elastography and the approach used depends on the type of trading company providing the technology. However, the transvaginal elastographic approach presents some technical challenges compared to the elastography performed through the linear and convex ultrasound probe that contribute to limit its widespread clinical use [25].

Also of interest is the list of the most cited papers. The list includes the top pioneering works describing the feasibility of elastography in cervical stiffness assessment. These initial studies are generally cited when referring to the historical basis of development of this new ultrasound tool. Other papers included in this list are further original studies on feasibility and reliability applied to the study of the cervix during pregnancy, as well as reviews and opinion papers.

Bibliometric analysis of the topics considered is interesting. This could be evaluated searching for the most used MESH terms and for the words included in the abstracts. According to these criteria, the most studied field of cervical elastography involved obstetrical topics, above all the diagnosis and prediction of cervical ripening, preterm delivery, and labor induction. The mechanisms underlying cervical ripening and its prediction in cases of preterm delivery and labor induction remain one of the unresolved topics in obstetrics. To date, the gold standard is the digital palpation of the cervix and the classification of its characteristics according to the Bishop score [26]. Nonetheless, this remains only a subjective and semi-quantitative evaluation and quantification of cervical softness could provide important information for a more effective study and for a better understanding of these mechanisms [27]. A further, non-obstetrical, topic evaluated with elastography was the diagnosis of cervical malignancies, even if the only study published in this context was a feasibility study [28].

Conclusions

Bibliometric study of a field, like cervical elastography, seems to have promise in defining specific parameters for quantifying its impact on medical research. This information is interesting in monitoring but also orienting new research, as well as editorial choices [29]. However, when strengthening the measurability of a scientific paper, an important question remains open. This regards the quality of this scientific production. Indeed, even though the number of papers produced in a specific medical area and the number of citations reached appear to be the best surrogate parameters we currently have, this does not always guarantee it. Indeed, quality is a complex concept. It can include several characteristics of a paper that could be of different in-

terest according to the focus of the editor or of the reader. Searching for more parameters to be monitored when considering scientific production remains a central topic in the future.

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