Application of Extensible Markup Language (XML) in Medical Research

A Bibliometrical Analysis

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Abstract: One of the most innovative web standards is the Extensible Markup Language (XML) which allows structured data storage and exchange and the creation of user defined tags for semantic processing. This bibliometrical analysis aims at describing the application of XML in medical research. Medline/PubMed was searched for relevant publications from 1997 to 2010 using the search term "XML" in all fields. All articles were bibliometrically analysed with respect to their year of publication, language, keywords, MESH-Headings, Impact factor, number of authors, number of pages. We found a total of 932 articles on XML from 1998 to 2010 mostly published in English (n=891; 95.6%). The mean impact factor was 1.93 ± 2.75 and increased from 1.78 ± 3.09 before 2005 to 2.12 ± 2.29 after 2005. Analysis of MESH headings led to the conclusion that XML predominantly is used in lab research while clinical and health services research only plays a minor role. As a conclusion, publications on XML impressively show that XML has become a standard for many software-tools and is more and more recognized in handling huge amounts of data. Applications in the field of health informatics are reasonable to expect in the future.

1 INTRODUCTION

Already in the early years of information technology in 1988, Gorry et al. pointed out that "the technical complexities of biomedical research almost always demand group effort". They also state that "groups that wish to prosper must continually improve their effectiveness, perhaps through the use of advanced information technology." (Gorry et al., 1988). They proposed the development of a "virtual notebook" which incorporates information resources like MEDLINE "with user-specified rules and stored in designated hypertext structures". Almost at the same time Sengupta discussed "issues of heterogeneity in computer systems networks, databases and presentation techniques, and the problems it creates in developing integrated medical information systems" (Sengupta, 1989). Both authors recommend the development of a comprehensive strategy to solve these problems by means of intelligent information-sharing systems.

Up to the early 1990s, the Internet was mainly used by academic or military institutions for communication and file transferring when in 1993 providers were permitted to sell internet connections to individuals. This changed the complete situation and masses of users went "online" (Doyle et al., 1996) and a variety of applications like internet access for community hospital libraries (Rambo & Fuller, 1993) or web based protein databases (Lemkin et al., 1995) were suggested. From that point the internet evolved dramatically and Hypertext Transfer Protocol (HTTP V1.0) alongside with Hyper Text Markup Language (HTML V2.0) as the main markup language for web pages together with web browsers were invented and applied i.e. to "open new possibilities for electronic publishing and electronic journals" (Pallen, 1995).

Parallel to this development the first Working Draft of an Extensible Markup Language (XML) specification was published and in 1998 XML 1.0 was recommended by the World Wide Web Consortium (W3C) (Treese, 1998).

XML documents according to the W3C "are made up of storage units called entities, which contain either parsed or unparsed data. Parsed data is made up of characters, some of which form character data, and some of which form markup. Markup encodes a description of the document's storage layout and logical structure. XML provides a mechanism to impose constraints on the storage layout and logical structure" (Bray et al., 1997).

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Thus, XML can be used to unite structural properties of databases, web requirements and the demands of end users. This is mainly done by using eXtensible Style sheet Language Transformations (XSLT) which includes XML oriented vocabulary for specifying the output format of XML. Therefore XML is often attributed as a main standard in semantic web technology (Robu et al., 2006). Furthermore the use of the unicode standard enables xml documents not only to be machine- but also human-readable (Bray et al., 2008).

Today a huge variety of XML-based applications like RSS, SOAP have been developed and XML-based formats have become the standard for many software-tools like open office. In the context of medical research, XML applications are applied in a variety of fields ranging from lab research to application in health services research. But also web applications in the field of health information libraries like semantic bibliographic search engines make use of the potentials of XML (Ostermann et al., 2009).

Up to now, information about these applications has not been analysed systematically. Thus, there is a basic need to give a bibliometric overview on the application of XML in medical research. This article aims at giving such an overview by analysing articles on XML in journals listed in MEDLINE.

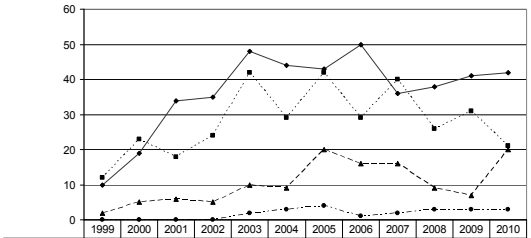
2 MATERIAL AND METHODS

In March 2011 Medline/PubMed was searched for articles about XML from 1999 until 2010. To get the broadest possible overview only "XML" was entered as a search term for all fields. Basic bibliometrical data from the articles found this way was directly downloaded from PubMed by using the csv-download option. This file included PMID, Title, Authors, Journal, Year, language, and length of the paper. If available official impact factors were retrieved from the yearly Journal Citation Reports and mapped to this data. Finally, MeSH descriptors from the articles as well as its origin were extracted from an xml-download and transformed and also added to the csv-extraction sheet.

Bibliometrical analysis was performed for the complete dataset and subdivided for the publication year using publication year's median as the splitting cut point. Nominal variables were analyzed using cross tabulations and Chi-Square-Test statistics while metrical data was described in terms of Mean ± Std.-Dev. and Median and rank test statistics. All statistical analyses were carried out using SPSS Version 19.

3 RESULTS

PubMed search found a total of 923 bibliographical records from 1999 to 2010. While at the beginning articles on XML were seldom (1999: 24 articles, 2000: 47 articles) a first peak was reached in 2003 with 102 articles. After a decrease in 2004 with only 85 articles the highest number of articles in Medline was obtained in 2005 with a total of 109 articles. From 2005 publication activity decreased again to a local minimum in 2008 with only 76 articles, which finally went up to 86 publications in 2010. With respect to their origin, the majority of publications came from Europe (n=440; 47.7%) closely followed by American publications (n=337; 36.5%), while publications from Asia (n=125; 13.5%) and Australia (n=21; 2.3%) only play a minor role. No publications came from Africa. In more detail, the majority of publications was published by US-American research groups (n=301; 32.6%, followed by Germany (n=116;12.6%) the UK (n=102;11.1%), France (n=49; 5.3%) and Japan (n=47; 5.1%). A closer look at the chronological development of percentages reveals that in the early years, American publications ranged first but after 2000 declined and only managed to be above Europe in 2007 (Figure 1).



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Europe	10	19	34	35	48	44	43	50	36	38	41	42
America	12	23	18	24	42	29	42	29	40	26	31	21
Asia	2	5	6	5	10	9	20	16	16	9	7	20
Australia	0	0	0	0	2	3	4	1	2	3	3	3

Figure 1: Number of publications on XML subdivided by their origin and year of publication.

The median number of authors in all years ranged between 3 and 4 and the number of descriptors (keywords) ranged between 5 and 8. Number of pages increased within the course of time from a median of 6 before 2005 to 7.5 after 2005 ($p<0.001$; Mann Whitney U-Test, Table 1).

Even more important than authors and page numbers is the development of the impact factor and the fields of research of publications on XML.

Table 1: Sample description.

	≤ 2005	> 2005	Total
# of articles	489	434	923
Mean per year	70	87	77
# of authors	4.3 ± 3.2	5.0 ± 3.7	4.6 ± 3.5
Mean	4	4	4
Median			
# of pages	7.0 ± 4.3	8.2 ± 4.5	7.6 ± 4.5
Mean	6	7.5	6
Median			
Origin	233 (47%)	207 (47%)	440 (47%)
US	190 (39%)	147 (34%)	337 (36%)
Asia	57 (12%)	68 (16%)	125 (14%)
Europe	9 (2%)	12 (3%)	21 (2%)
Australia			
Language	477 (98%)	405 (93%)	882 (96%)
English	12 (2%)	29 (7%)	41 (4%)
Others			
Impact factor	1.8 ± 3.1	2.1 ± 2.3	1.9 ± 2.8
Mean	0	1.46	0.69
Median	47%	59%	53%
% IF-Journals			
# descriptors	7.6 ± 3.9	6.9 ± 4.1	7.3 ± 4.0
Mean	7	7	7
Median			

Impact factor (IF) increased from a mean of 0.8 in 1999 to a mean of 2.65 in 2004 and decreased again until 2008 where IF reached the maximum of 3.1 (both mean and median) but then decreased again. Compared to the time before 2005 IF has significantly increased from 1.8 ± 3.1 to 2.1 ± 2.3 after 2005. One reason for this development is reflected by the percentage of journals with impact factor which significantly ($p<0.001$; Chi-Square-Test) increased from 47.0% before 2005 to 58.8% after 2005. Figure 2 shows this development in more detail.

A more detailed analysis with respect to the origin of the papers also reveals that there is a small but significant difference between publications from Europe (Mean IF=2.00 ± 2.76) and America (IF 2.12 ± 2.94), which is also reflected in the course of time (Table 2).

Again US-American publications on XML cumulated the highest impact (300 publication with a IF-sum of 626.47).

With the highest IF-mean per publication of 3.52 the UK cumulates to a total sum of 359.23 IF-points from 102 articles. Only Canada has a comparable IF-mean with 2.82 from 31 publications, while Germany only adds 159.62 IF-points from 116 publications and Japan adds 96.72 points out of 47 publications. A more detailed analysis of the journals XML-articles were published in reveals that

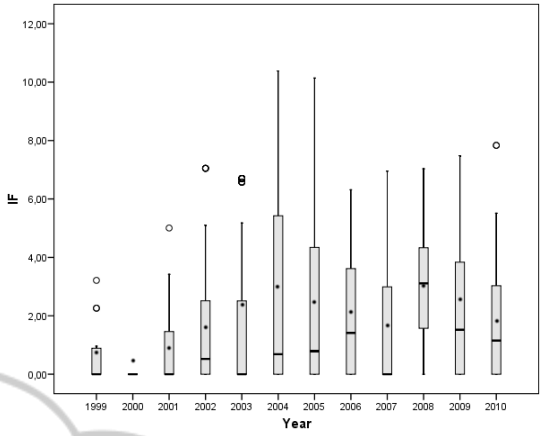


Figure 2: Boxplots of the development of Impact factor of XML-publications within the course of time.

Table 2: Development of Impact factor subdivided by origin and year of publication.

	Europe		America	
Year	N	IF (M±SD)	N	IF (M±SD)
1999	10	1.29 ± 2.81	12	0.53 ± 0.88
2000	19	0.32 ± 1.24	23	0.63 ± 1.27
2001	34	1.08 ± 1.43	18	0.92 ± 1.68
2002	35	1.37 ± 2.14	24	2.03 ± 2.37
2003	48	2.35 ± 5.14	42	2.00 ± 2.61
2004	44	2.36 ± 2.91	29	3.69 ± 4.50
2005	43	1.96 ± 2.48	42	2.78 ± 4.23
2006	50	2.25 ± 2.21	29	1.73 ± 2.31
2007	36	1.63 ± 2.15	40	2.07 ± 2.62
2008	38	3.24 ± 2.07	26	3.19 ± 2.61
2009	41	2.36 ± 2.44	31	2.22 ± 2.41
2010	42	2.05 ± 2.08	21	1.67 ± 2.31
Total	440	2.00 ± 2.76	337	2.12 ± 2.94

four from the Top-10 Journals covering 254 articles did not have an Impact factor at the time of publication (Table 3).

In particular, the journal "Studies in health

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Table 3: Top-20 list of journals with XML-publications and their Impact factor.

Rank	Journal	N	%	IF Sum
1	Stud Health Technol Inform	135	14.6	0.00
2	Bioinformatics	83	9.0	443.21
3	AMIA Annu Symp Proc	60	6.5	0.00
4	BMC Bioinformatics	52	5.6	187.74
5	Nucleic Acids Res	51	5.5	355.05
6	Int J Med Inform	33	3.6	54.82
7	Proc AMIA Symp	33	3.6	0.00
8	Conf Proc IEEE Eng Med Biol Soc	26	2.8	0.00
9	Comput Methods Programs Biomed	19	2.1	15.52
10	J Am Med Inform Assoc	19	2.1	50.65
11	BMC Med Inform Decis Mak	14	1.5	8.59
12	J Med Syst	14	1.5	6.38
13	J Digit Imaging	13	1.4	13.46
14	Methods Inf Med	13	1.4	15.43
15	IEEE Trans Inf Technol Biomed	11	1.2	16.02
16	Proteomics	11	1.2	53.48
17	J Chem Inf Model	10	1.1	33.77
18	Brief Bioinform	7	0.8	16.58
19	J Med Internet Res	7	0.8	3.59
20	Med Inform Internet Med	7	0.8	8.47
Total		618	67.0	1282.76

technology and informatics" ranks first in 7 of 12 years. Other journals however from the field of Medical and Bioinformatics with mean impact factors greater that three do however compensate this resulting in a mean IF of 2.08 in the Top-20 list of journals.

4 CONCLUSIONS

This articles aimed at summarizing the development of publications on XML in the medical literature from 1999-2010. Based on our findings the main period of visibility and productivity can be identified in the year 2004. At that time the second edition of XML 1.1 was initially published (Bray et al., 1997). While XML 1.1 is not widely implemented, XML 1.0 has been developed further to its fifth edition which came out in 2008 (Bray et al., 2008). This year denotes the second high peak in publications and Impact factors. Although versions of XML have changed in the course of time, its applications are still given in knowledge transfer in the life science (Murray-Rust, 2000) and the creation of interfaces for related web-based information systems (Badard and Richard, 2001). The application of XML in Materials and Hospital Management however only plays a minor role although Katehakis et al. (2001) quite early have pointed out the importance of XML for health services research: "XML provides the appropriate technology and makes up the most convenient vehicle towards a common format for delivering and presenting information content. Elaboration of the standard DTD logical structure and related XML infrastructure will make information personalization flexible and generic enough to adapt to various types of users and client devices." In particular with the upcoming research in individualized and personalized medicine at that time (Ginsburg and McCarthy, 2001) XML has managed to become a standard in clinical laboratory procedures (Saadawi and Harrison, 2003) but its way into patient care still seems to be far behind the possibilities XML is offering: XML-based electronic medical records may i.e. be used to extract experiential clinical knowledge. Abidi & Manickam (2002) proposed "an automated approach to generate cases for medical case-based reasoning systems" using XML.

Another field of application is the development of XML-based search engines. Finding information in the World-Wide Web is still a crucial matter in clinical and health services research. Already in the beginning of XML Butler reported on sophisticated and specialized search technologies like natural language processing to assist researchers in finding information. Meanwhile several XML-based search engines and tools have been developed in a variety of fields like Complementary Medicine (Ostermann et al., 2004), E-Health documents (Gaudinat, 2006), Proteins and Protenomics (Keller et al., 2005).

Moreover the bibliometric analysis on XML publications also shows a widespread use of this technology all over the world. More than 44 nations including Saskatchewan, Jamaica, Ecuador and Malaysia underpin the international importance XML has gained since 1999. However, most of the publications origin from the main player nations in the field of information technology namely the US, Germany and the UK.

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As a limitation of this review, it has to be noted that it only focusses on XML as one of many concepts of the semantic web. Apart from XML many data representation and communication standards have been developed in the last two decades. One of the most important standards is given by Resource Description Frameworks (RDF). While XML is a document format for writing and exchanging information on the Web RDF is a model for describing semantics and reasoning about information on the Web (Patel-Schneider & Siméon, 2002).

Already two year earlier than Patel-Schneider and Siméon, Decker et al. argued that semantic interoperability should be achieved by exploiting RDF as a metadata data model (Decker et al., 2000). Some authors even argue that RDF will be the universal exchange language of future healthcare due to its self-describing structure which is easy to generate (Booth et al., 2013). Moreover RDF might be more powerful in "large-scale information integration and vocabulary evolution problems".

Although the argumentation is straight and RDF gains more and more attention, it must be noted that articles on RDF in contrast to XML are quite rare. Thus, we decided to focus on XML for this current review which does not imply a voting for XML as a solitary standard of the semantic web.

Future development according to a recent position paper of Baclawski & Schneider (2009), is going to develop information infrastructures based on Open Ontology Repositories (OOR) combining existing ontologies with innovative information technology architectures and standards. XML in this vision is one but not the only leading standards that may foster collaborative administration of knowledge and metadata.

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