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Review

# A bibliometric analysis of the citation classics of acute appendicitis

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## HIGHLIGHTS

- Hundred most cited articles on appendicitis. Six level 1a, 20 studies at level 1b.
- Most cited articles on appendicitis higher quality evidence only in more recent times.

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## ABSTRACT

*Introduction:* Acute appendicitis is one of the most commonly encountered emergency surgical conditions. An understanding of the most highly cited research works in this field is key to good evidence based clinical practice.

*Aims:* To perform a bibliometric analysis on the 100 most frequently cited articles in the field of acute appendicitis.

*Methods:* The database of the Institute for Scientific Information (ISI) Web of Science Expanded citation index was searched to identify the 100 most frequently cited articles in the field of acute appendicitis. The web of science expanded citation index tracks article citations made since 1946.

*Results:* The top 100 most frequently cited articles were selected for analysis in this series. The most frequently cited article was cited 649 times and the least cited three article 93 times. The average number of citations per article was 167.74. The top 100 cited articles originated from 17 countries. Over half of the papers originated from the USA. Fifty-one of the papers concentrated on diagnostics of acute appendicitis. Thirty-six papers looked at the treatment of acute appendicitis with 30 of these dealing with the surgical management of the disease. There were 6 studies at level 1a, 20 studies at level 1b and 43,5,17 and 9 studies at levels 2, 3, 4 and 5 respectively.

*Conclusions:* Bibliometric analysis of the citation classics in a given field can provide interesting insights into the relationship between the quality of research outputs and clinical practice. The study of acute appendicitis remains an active field of research with a growing body of higher quality evidence underpinning our clinical practice.



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## 1. Background

The earliest known documentation of practice in the field of appendicitis dates back to Berengarius Carpus, professor of surgery at Pavia and Bologna universities, who described the appendix in 1522 [1]. The first successful appendectomy was performed in 1735 by Claudius Amyand. In 1886 Reginald Heber Fitz published a paper on appendicitis and named the procedure an appendectomy [2].

Appendicitis, as the most common general surgical emergency [3], generated an enormous body of medical literature over the course of the 20th and early 21st centuries still impose a research conundrum as there is little representation of new understanding on appendicitis in a high quality research [4].

The science of bibliometrics is the branch of information science which deals with the study of the meta-data surrounding published material [5]. This data can be used to quantify and characterise published works in order to obtain an overview of the major outputs within a given field of study. The citation index of a paper reflects the total number of citations of that paper that have accrued over time and can be taken as a proxy indication of the overall impact of that article on the field to which it refers [6].

Recently, bibliometric studies of the medical literature have appeared in increasing numbers. Many institutions are making use of bibliometric analyses to assess their research output and performance and several journals publish their own series of so called "citation classics" [7].

The purpose of this study was to identify the most frequently cited articles in the field of acute appendicitis and to perform a bibliometric analysis to elicit the characteristics of this body of work.

To date, no bibliometric analysis of the research outputs in this field has been undertaken.

### 1.1. Methods and design

The database of the Institute for Scientific Information (ISI) Web of Science expanded citation index tracks all article citations made since 1946 (therefore any citations that predate this cannot be tracked). This database was searched by topic on February 24th, 2016 using the keywords "Appendicitis"; "Acute Appendicitis"; "Appendectomy" and "Appendicectomy" to identify citation classics in the field of acute appendicitis. These articles were then ranked in order of number of citations received by each publication and the one hundred most frequently cited articles were selected for inclusion in our analysis. The abstracts of these articles were obtained to determine their relationship to appendicitis. Any article not directly related to the main topic of study was to be discarded and the next most cited article retrieved until the 100 most cited and directly related articles were obtained.

The full text of each article in this series was then obtained and reviewed by the authors. The following data was extracted: Article title, type of article, journal of publication, institution, country of origin, authorship, number of citations, year of publication and level of evidence. Each paper was assigned to a single country of origin according to the corresponding author. The articles were classified according to their status as clinical or non-clinical studies, whether they dealt with basic science, diagnostics or therapeutics.

### 1.2. Results

The search retrieved 10975 articles. Fifteen articles were excluded on the basis of irrelevance to appendicitis.

The most frequently cited article was cited 649 times and the least cited three article 93 times. These most cited articles were published between 1971 and 2010 (Fig. 1). The average number of

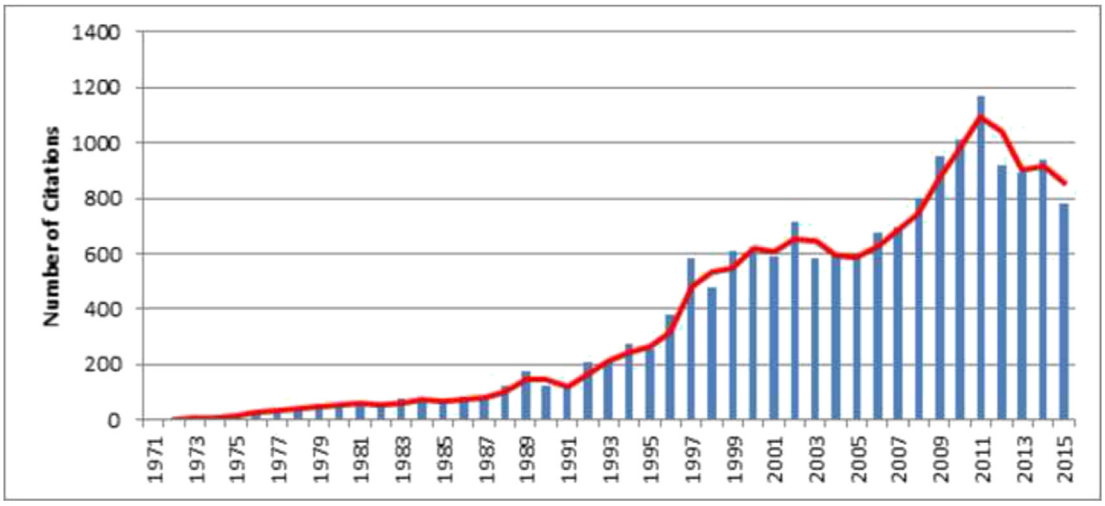


**Fig. 1.** Number of citations per year.

**Table 1**
Countries of origin of the top 100 cited articles.

| Rank | Country | No. of articles |
|---|---|---|
| 1 | USA | 57 |
| 2 | Sweden | 10 |
| 3 | UK | 7 |
| 4 | Canada | 4 |
| 5 | Germany | 3 |
| 5 | Netherlands | 3 |
| 5 | Denmark | 3 |
| 6 | Ireland | 2 |
| 6 | Belgium | 2 |
| 7 | Italy | 1 |
| 7 | New Zealand | 1 |
| 7 | Hong Kong | 1 |
| 7 | Australia | 1 |
| 7 | Singapore | 1 |
| 7 | Norway | 1 |
| 7 | Turkey | 1 |
| 7 | Israel | 1 |
| 7 | India | 1 |

citations per article was 167.74.

### 1.3. Origins

The top 100 cited articles originated from 17 countries – with more than half (57) coming from the USA alone. The next most represented nations were Sweden with 10 papers and the UK with 7 (Table 1).

Sixty-six institutions produced the 100 articles in the series. The institution with largest number of first author publications produced is Massachusetts General Hospital with 6 publications. This is followed by Department of Surgery, County Hospital Ryhov, Jonkoping, Sweden; Stanford University; and the Karolinska Institute which have 4 papers each. New York University; Univeristy of Pennsylvania; University of Southern California; University of Washington and the Children's National Medical Center have three publications each (Table 2).

### 1.4. Authorship

Articles were analysed according to lead author. 80 authors were the lead author of one publication alone. The lead author with the highest number of publications in the series is Patrick M. Rao who has been lead author on 5 of the top 100 articles. Roland E. Andersson has lead-authored 4 publications. Emil J. Balthazar has lead-authored 3 articles. Julien B. Puylaert; R. Brooke Jeffrey; David R. Flum and Michael J. Lane have two lead-authored publications each (Table 3).

When analysis was extended to include non-first authors, Four authors were involved in 5 publications each. One author was involved in 4 papers. Three authors were involved in 3 publications each. Twenty-six authors were involved in 2 of the 100 articles. Sixty-six authors had involvement with just one of the articles within the series.

**Table 2**
Institutions with three or more top-cited articles.

| Rank | Institutions | No. of articles |
|---|---|---|
| 1 | Massachusetts General Hospital | 6 |
| 2 | Dept of Surgery, County Hospital Ryhov, Jonkoping, Sweden | 4 |
| 2 | Stanford University | 4 |
| 2 | Karolinska Institute | 4 |
| 3 | New York University | 3 |
| 3 | University of Pennsylvania | 3 |
| 3 | University of Southern California | 3 |
| 3 | University of Washington | 3 |
| 3 | Children's National Medical Center, Washington | 3 |

**Table 3**
Lead authors with more than one publication in the series.

| Rank | Author | No. of articles |
|---|---|---|
| 1 | P. M. Rao | 5 |
| 2 | R. E. Andersson | 4 |
| 3 | E. J. Balthazar | 3 |
| 4 | J. Puylaert | 2 |
| 4 | R. B. Jeffrey | 2 |
| 4 | D. R. Flum | 2 |
| 4 | M. J. Lane | 2 |

### 1.5. Journals and quality

Publications from 36 different journals were represented in our retrieved sample with the journals “Radiology”, “Annals of surgery” and “British journal of surgery” the top three contributors with 15, 13 and 11 papers respectively (Table 4). The 100 papers were of a wide range of evidence levels when graded according to the guidance on levels of evidence from the Oxford Centre for Evidence-based medicine.

There were 6 studies at level 1a, 20 studies at level 1b and 43, 5, 17 and 9 studies at level 2, 3, 4 and 5 respectively (Fig. 2).

### 1.6. Content and focus

Of the 100 articles, 87 were clinical studies, 3 concerned basic science and 10 were review articles (Fig. 3). Almost half of the papers (51) concentrated on diagnostics of acute appendicitis. 26 of these concerned imaging modalities, 11 focussed on clinical aspects of the diagnosis of acute appendicitis (Appendix 1).

Thirty-six papers looked at the treatment of acute appendicitis. 30 of these dealt with the surgical management of the disease, 4 addressed antimicrobial treatment of acute appendicitis and the remaining 2 papers compared antimicrobial vs. surgical treatment for acute appendicitis.

Within the sphere of surgical treatment of the disease, 18 papers dealt with laparoscopic versus open appendectomy. The top cited papers on laparoscopic appendectomy are presented in Appendix 2.

The oldest publication in the top 100 cited articles was published in 1971. The 1970s delivered 6 articles. The 1980s saw an increase with 15 publications from this decade making it into the most cited 100 articles. The earliest level 1 evidence (1b) in the series of citation classics is also from the 1980s and this was a clinical trial by Jess et al., published in American Journal of Surgery in 1981.

When analysed according to publications per year, the decade from 1990 to 1999 produced the most citation classics with 46 articles, followed by the decade from 2000 to 2009 with 32 papers (Fig. 4). Of the 46 articles from 1990 to 1999, 16 are level 1 evidence (3 level 1a, 13 level 1b). Of the 32 articles from the decade 2000–2009, 8 are of level 1 evidence quality (2 level 1a, 6 level 1b). The current decade has so far produced 1 article in the top 100 citation classics and this is of level 1a quality from the Cochrane database of systematic reviews.

## 2. Discussion

The 20th century saw an explosion in research output across all medical and scientific fields. Surgical practice as it pertains to

**Table 4**
Journals with more than citation classic.

| Rank | Journal | No. Of articles |
|---|---|---|
| 1 | Radiology | 15 |
| 2 | Annals of Surgery | 13 |
| 3 | British Journal of Surgery | 11 |
| 4 | American Journal of Surgery | 5 |
| 4 | American Journal of Roentgenology | 4 |
| 4 | Journal of Pediatric Surgery | 4 |
| 4 | New England Journal of Medicine | 4 |
| 4 | World Journal of Surgery | 4 |
| 5 | Archives of Surgery | 3 |
| 5 | Journal of the American Medical Association | 3 |
| 6 | American Journal of Epidemiology | 2 |
| 6 | British Medical Journal | 2 |
| 6 | European Journal of Surgery | 2 |
| 6 | Gastroenterology | 2 |
| 6 | Journal of The American College of Surgeons | 2 |
| 6 | Obstetrics and Gynecology | 2 |
| 6 | Surgery | 2 |
| 6 | Surgical Endoscopy and Other Interventional Techniques | 2 |

appendicitis has been no exception, and a consistent year on year increase in frequency of publications has been seen throughout the decades [8]. The search engine Pubmed currently (March 2016) tracks some 20883 articles featuring the word appendicitis and as our search using Web of Science TM Core Collection in this case demonstrates (10975 articles) the extant body of literature in this field is large and growing (Fig. 5).

Bibliometric analysis may allow us to observe trends within the literature, to draw conclusions about the impact of published material on clinical practice, and importantly, to direct research efforts and funding in a more informed way.

Citation number is an often recognised metric for assessing the relative impact of published material within a scientific field [9] and the 100 most frequently cited articles in a given field of study are commonly referred to as "citation classics" [10]. In this series, however, only 6 of those 100 most cited articles are found to be of level 1a evidence quality. Of these, the first was not published until the late 1990s (R. Golub et al., JACS 1998). There are a further 20 articles of level 1b evidence quality, but all bar one of these was published after 1990. This draws into question the relationship between the quality of the published evidence in a given field and its quantifiable impact on the published literature within that field.

It is significant that a number of the most cited articles were published in journals that are not in themselves core surgical journals – Radiology, with 15 of the 100 publications, makes up the largest contributor. Then others such as American Journal of Roentgenology, American Journal of Epidemiology, Gastroenterology, and Obstetrics and Gynaecology all make significant up a contribution to the series with 10% of the papers.

Bibliometric analysis may offer insights into the relationship between the research outputs in a given field and the established clinical practice in that field. One could reasonably expect that a sea-change in clinical practice might be precipitated by high level

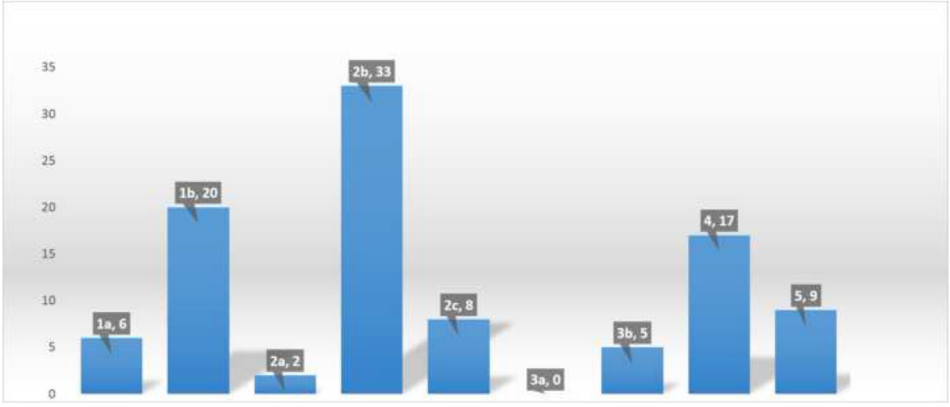


**Fig. 2.** Levels of evidence of citation classics.

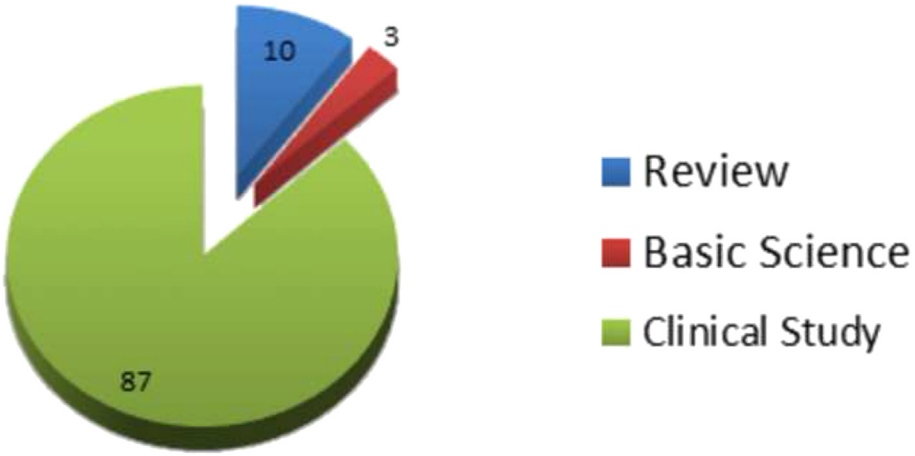


**Fig. 3.** Study types of citation classics.

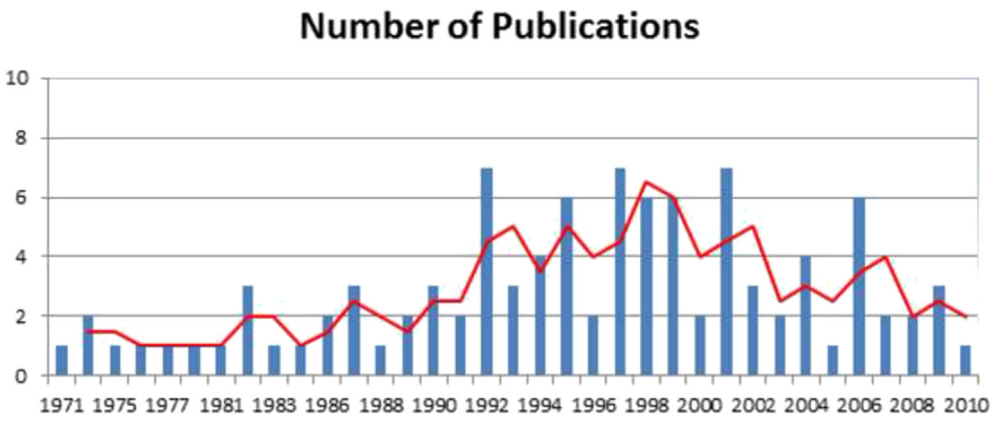


**Fig. 4.** Number of publications per year.

evidence, rather than retrospectively followed up by it as in a post-hoc analysis of the results of a given practice. In the above series however, we can see that although laparoscopic appendectomy was commonplace at the end of the 1990s, one could argue that the randomized clinical trials from this era were in fact a consequence of this already established practice, or paralleled the implementation of laparoscopic appendectomy rather than a necessary prelude to establish its safety and efficacy. The same could be said not only on acute appendicitis but studies on other treatments or diseases [11]. Overall randomized control trials comparing open versus laparoscopic were reported to be low quality especially early ones as most did not comply with the CONSORT requirements published first in 1996 [12,13].

There are 9 randomized clinical trials of laparoscopic vs open appendectomy in the 1990s in our series. The first metaanalysis of this topic appears in 1998. This delay cannot be explained by the obvious time lag between production of evidence and production of a metaanalysis of that evidence alone. The highest cited paper on this topic (Attwood et al., in 1992) was published nearly ten years after the first paper on laparoscopic appendectomy by Semm in 1983. If we are to argue that the progression from open to laparoscopic surgery for appendicitis was evidence based, we must accept that this body of evidence did not have such impact in research terms as to make its appearance felt within this set of citation classics. There is some evidence to suggest that clinicians are slow to adopt new practices even in the face of evidence or guidelines and the true drivers of practice change can be obscure [14,15].

The critics of bibliometric analyses argue that papers are not cited because they represent the best academic quality but to refer to results from earlier work or a method, to give credit to partial results towards the same goal, to back up some terminology, to provide background reading for less familiar ideas, and sometimes to criticize not to mention less honourable reasons [7,16]. For example, highest cited paper in our bibliometric review with 649 citations (Addiss D.G.et al., 1990) concerns the epidemiology of appendicitis in United States. This work may be cited highly in other epidemiological literature, or one could argue that this paper is regularly cited as it provides high quality background information and therefore may be referred to when writing an introduction to any research article on that disease.

## 3. Limitations

The Web of Science core citation index only tracks citations made since 1946, and therefore cannot account for any potentially highly cited works that have attracted citations before this point, although as demonstrated by the pattern in Fig. 5, the number of publications before this time is not likely to be large. Research articles may need at least three years after publication to accumulate citations to have reliable bibliometric measure [17]. Although citations continue to accumulate with time which means our "classics" are biased towards older papers [7]. We can therefore infer that there may be already extant high impact papers which have not yet accrued enough citations as to enter into this series. For example, the growing and controversial area of non-surgical treatment of acute appendicitis, features in just three papers in this series (the earliest of which was published in 1995). This study has focused on entries contained in the Web of Science only, and it

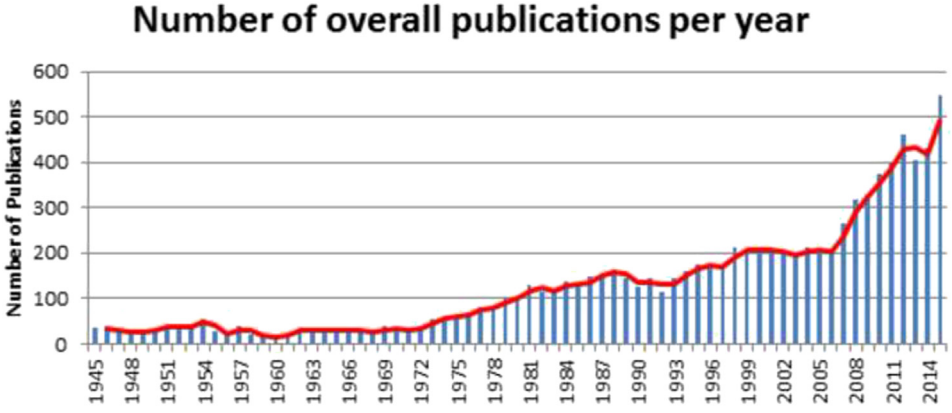


**Fig. 5.** Number of overall publications per year.

should be noted that the employment of other databases including PubMed and Scopus may have yielded slightly different results.

Citation index alone cannot tell us about the context in which a citation was made, and so one cannot know if the highest cited works are themselves always the strongest drivers of changes in clinical practice [18].

## 4. Conclusions

The citation classics of acute appendicitis represent a broad range of medical surgical and scientific disciplines and are published within a diverse range of journals. Acute appendicitis still remains diagnostic challenge and it is reflected in "citations classics" with over half of the works represented here (n = 51) concern diagnostics, with 26 of these dealing with diagnostic imaging. Whilst the largest portion of the evidence is of level 2b quality, increasingly higher quality evidence has been produced in more recent times. Within this space, one cannot make a definite connection between the quality of a piece of evidence and its subsequent impact on the literature itself or, by inference, upon clinical practice, as is demonstrated by the presence of many highly cited works of level 3, 4 and 5 evidence within this collection (n = 31).

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## Author contribution

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## Conflicts of interest

None.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.amsu.2017.05.034.

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