

# The 100 Most Influential Manuscripts in Laparoscopic Adjustable Gastric Banding: A Bibliometric and Altmetric Analysis

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## Abstract

**Background:** Bibliometric analysis identifies the most cited publications, which define understanding of Laparoscopic Adjustable Gastric Banding (LAGB). In this study, the 100 most cited articles in the field of LAGB were studied and correlation between Total Citation Count (TCC), Citation Rate Index (CRI), Level of Evidence (LOE), and Altmetric Attention Scores (AAS) analysed.

**Methods:** The Thomson Reuters Web of Science database was used to identify relevant English language articles using the search terms: ((laparo\* and adjust\* and gastr\* and band\*) OR (LAGB or L.A.G.B.)) AND ALL FIELDS: ((endoscop\* or remov\* or complicat\*)). The 100 most cited papers analysed.

**Results:** 1,473 articles were returned with median citation count of 122 [interquartile range (IQR):96.75–215.25]. The most cited article was 'Surgical Treatment of Obesity' by Maggard et al. (962 citations). The journal "Obesity Surgery" published the most papers within the top 100 and had the highest TCC (n=36, 5633 citations). The article with the highest AAS. LOE was significantly related to TCC (p=0.0029), CRI (p=0.00002) and AAS (p=0.00173). Articles published post-2006 had a higher AAS compared to pre-2006 (p=0.00001). The AAS of articles published pre-2006 were not correlated with the TCC (r=0.2332, p=0.1108) but had a positive correlation with the CRI (r=0.3194, p=0.0268). The AAS post-2006 did not have a significant correlation with TCC (r=0.5274, p=5.8596) or CRI (r=0.5274, p=5.8596).

**Conclusion:** Bibliometric indices provide an important perspective on article impact and are related to evidence level. AAS and, consequently, social media impact is now a valid measurement of academic impact.

**Keywords:** Obesity; Overweight; Laparoscopy; Laparoscopic adjustable gastric banding

## Introduction

Laparoscopic adjustable gastric banding (LAGB) is one of the most popular operations performed worldwide for morbid obesity [1]. There is an ever expanding body of evidence about LAGB which includes indications, effect on weight loss and improvement of associated comorbidities, common complications and long-term outcomes. One of the methods of identifying the published research work that has had the greatest impact on our understanding of the various aspects of LAGB is by generating and analysing a citation rank list. A citation is generated when a published article formally references another article and it is now widely accepted by the academic medical community that research impact is strongly correlated with the number of citations [2]. Bibliometrics is a branch of information research which deals with the study and analysis of meta-data surrounding published material [3]. Citation analysis is a branch of bibliometrics that evaluates the impact of an article or journal based on the total number of citations received by that article. Detailed review and statistical analysis of the publications in the citation rank list provides valuable information and insight into the types of research studies that influence and generate interest in the academic world. To date, there has been no study undertaken to identify and analyse the most influential publications in the context of LAGB.

Citation count is now a well-established method within the field of Bibliometrics to measure the impact of a published research study but it does have some recognised weaknesses. For example, papers with very high original impact can become a victim of their own success as far as citations are concerned due to the phenomenon of obliteration by incorporation [4]. These papers tend to be cited with increasingly low frequency with time as the original findings become universally accepted within the academic community and therefore, no longer routinely referenced in published articles. Furthermore, the process

of accrual of citations is a slow process and takes several years. In an effort to circumvent this issue, other methods of assessing research impact more rapidly have been developed recently and are known as alternative metrics or "Altmetrics". These are based on utilisation of alternative information sources that are also considered as independent or surrogate markers of impact such as frequency of online article downloads, discussion in social media platforms, use in consensus or guideline development and mention in patent applications amongst others. One of the most popular platforms that is currently favoured by many journals to assess these alternative metrics is the Altmetric Attention Score (AAS) developed by Altmetric LLP. The AAS is a relatively new concept initiated in 2011 and is derived from algorithms which assess the distribution and influence of a scientific paper through social media and until recently was known simply as the 'Altmetric Score' [5]. There is an urgent need to conduct research that helps to assess the utility and value of Altmetric indices over more traditional indices of academic impact such as citation number (bibliometric index), journal impact factor and level of evidence of the publication.

The primary aim of this study is to identify and perform a citation rank analysis of the 100 most cited publications that have influenced the understanding of LAGB. The secondary aim is to analyse the correlation

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between Total Citation Count (TCC), Level Of Evidence (LOE) and AAS of the listed publications to gain a further understanding of the dynamics between these metrics and assess the reliability of AAS as an index of academic impact.

## Methods

A search of the Thomson Reuters Web of Science citation indexing database and research platform was performed using the search terms ((laparo\* and adjust\* and gastr\* and band\*) OR (LAGB or L.A.G.B.)) AND ALL FIELDS: ((endoscop\* or remov\* or complicat\*)). The returned dataset was filtered to include only English language and full manuscripts and sorted using the TCC in descending order as per the method originally developed by Paladugu and colleagues [6]. Each manuscript was analysed to ensure that content was relevant to the study topic and the four articles were excluded as they were deemed not to have substantial content related to LAGB [7-10]. The 100 most cited

manuscripts were subsequently analysed in detail and used to populate a database which included several data indices such as the publishing journal (name of journal, country of publication, 2018 impact factor and year of publication), authors (institutional affiliation and country) and article details (TCC, type of study, LOE and AAS). The quality of evidence contained within the articles was assessed and recorded according to the Oxford Evidence Based Medicine scoring system [11]. The "Altmetric it" application downloaded from the Altmetric.com website was used to generate Altmetric scores by utilising the journal article page containing the doi reference number [5].

## Results

The Web of Science search returned 1,473 full-length, English language papers. **Table 1** lists the 100 most cited of these papers: [12-109].

The total number of citations ranged from 78 for Skull et al. (Laparoscopic adjustable banding in pregnancy: Safety, patient

Rank	Citations	First author	Rank	Citations	First Author
1	962	Maggard, M	51	121	Friedenberg, F K
2	935	Dixon, J	52	120	Fried M
3	877	Flum, D R	53	118	Nguyen, N T
4	750	Angrisani, L	54	117	Dargent, J
5	678	Colquitt, J L	55	116	Mognol, P
6	662	Chang, S	56	114	Black, J A
7	551	Picot, J	57	114	Chevallier, J
8	439	Himpens, J	58	114	Favretti, F
9	395	Colquitt, J L	59	112	Angrisani, L
10	325	O'Brien, P E	60	112	Busetto, L
11	310	Tice, J A	61	111	Trastulli, S
12	280	Maggard, M	62	107	O'Brien, P E
13	272	Chevallier, J	63	106	Paulus, G F
14	262	Demaria, E J	64	106	O'Brien, P E
15	255	Rubino, F	65	105	Fielding, G A
16	250	Elder, K A	66	103	Parikh, M S
17	247	Angrisani, L	67	101	Pontioli, A E
18	244	Birkmeyer, N J O	68	101	Busetto, L
19	241	O'Brien, P E	69	100	Pontioli, A E
20	238	Gagner, M	70	100	Miller, K
21	224	Deitel, M	71	99	Cunneen, S A
22	220	Sauerland, S	72	98	Encinosa, W E
23	219	Himpens, J	73	97	Lancaster, R T
24	217	Weiner, R	74	97	Martikainen, T
25	216	Demaria, E J	75	97	Chelala, E
26	215	Nocca, D	76	96	Ponce, J
27	214	Dixon, J	77	94	Li, Vicky K M
28	213	Belachew, M	78	92	Frezza, E E
29	206	Belachew, M	79	91	Ahroni, J H
30	205	Fisher, B L	80	90	Steffen, R
31	194	Shi, X	81	90	Fielding, G A
32	192	Abbatini, F	82	90	Weiss, H G
33	192	Belachew, M	83	89	Wageningen, B V
34	178	Favretti, F	84	89	Ren, C J
35	175	Lalor, P F	85	86	Demaria, E J
36	173	Carlin, Arthur M	86	86	Ponce, Jaime
37	172	Angrisani, L	87	84	Ducarme, G
38	169	Treadwell, Jonathan R	88	84	Forsell, P
39	161	Nguyen, Ninh T	89	83	Nguyen, Ninh T
40	155	Lee, Crystine M	90	83	Bernante, Paolo

41	139	Inge, Thomas H	91	83	Frigg, Arno
42	139	Pontiroli, Antonio E	92	82	Parikh, Manish S
43	134	Zinzindohoue, Franck	93	81	Cottam, Daniel R
44	132	Favretti, F	94	81	Niville, E
45	131	Franco Juan V A	95	80	Vertruyen, Marc
46	131	Biertho, Laurent	96	80	Rubenstein, Richard B
47	129	Sugerman, H J	97	79	Nadler, Evan P
48	127	Westling, A	98	79	Ren, Christine J
49	125	Spivak, Hadar	99	78	Gumbs, Andrew A
50	123	Colquitt, Jill L	100	78	Skull, A J

**Abbreviation:** 'LAGB = Laparoscopic Adjustable Gastric Banding

**Table 1:** The top 100 most cited papers in LAGB<sup>1</sup>.

tolerance and effect on obesity-related pregnancy outcomes) to 962 for Maggard et al. (Meta-analysis: Surgical Treatment of Obesity) (Table 1). The median citation count was 122 (interquartile range (IQR): 96.75 – 215.25) and this was not normally distributed (Skewness=2.86, Kurtosis=8.29). The oldest article within this top 100 list was a report on LAGB published in 1994 by Belachew et al. titled 'Laparoscopic adjustable silicone gastric banding in the treatment of morbid-obesity – A preliminary report'. The most recent paper titled 'Bariatric surgery for obesity and metabolic disorders: state of the art' was published in 2017 by Nguyen et al.

The 100 most significant papers spanning between 1994 and 2017 were published across a spectrum of 28 journals with the number of published articles per journal ranging from 1 to 36 (Table 2). The journal "Obesity Surgery" published the highest number of papers within the top 100 and also, had the highest cumulative TCC amongst all journals (n=36, 5633 citations). Amongst this list of the top 100 articles, 11 publications were in 2002 making it the most frequent year of publication. Most articles were published in journals which had an impact factor (IF) greater than 3 with only 11 articles published in journals with a lesser IF.

The country with the most publications when first author affiliation was considered was the United States of America (USA) with 41 publications and, incidentally, USA also had the highest cumulative TCC at 8,174 (43% of total citations) (Figure 1). This was followed by Italy with 15 publications. Analysis of senior author affiliation revealed that the country with the most publications and the highest cumulative TCC was also USA (n=42, 5,954 citations, 31% of total citations) followed by Italy (n=17; 5404 citations). The country with the highest AAS by first author affiliation (1,350, 77% of total AAS) as well as second author affiliation (1,350; 76% of total AAS scores) was also USA. Monash University and its affiliated institutions had the highest number of articles in the top 100 with 6 publications.

There were two first authors with the highest number of publications in the top 100 with 4 articles each - Paul E. O'Brien who is affiliated with Monash University, and L. Angrisani who is affiliated with S. Giovanni Bosco Hospital and the Fondazione Institute for Spreading and Valorisation of Scientific Culture, they both had 4 publications each. L. Angrisani also had the most citations overall as first author with 1,281 citations. The senior author with the highest number of publications in the top 100 with 4 articles was G. Enzi who is affiliated with the University of Padova and the University of Padua. The senior author with the highest number of citations was Paul G. Shekelle who is affiliated with the RAND Health Division, California with 1,242 citations.

The citation rate index (CRI) was also calculated in order to control for the fact that older papers would have had more time to accrue citations. The CRI for the top 10 articles ranged from 187.5 for Angrisani et al. (Bariatric Surgery Worldwide, 2013) to 35.908 for Colquitt et al. (Surgery for Obesity, 2009) (Table 3). The highest 5 CRIs came from articles published between 2009 and 2017. The countries that published the highest number of articles in the top 10 CRI were UK and USA with 3 articles each.

The articles with the five highest AAS were published between 2009 and 2017 with the highest score being 413 (Perioperative Safety in the Longitudinal Assessment of Bariatric Surgery, Flum et al) (Table 4). Altmetric scores ranged between 0 and 413 (median = 0, IQR: 0 – 10.25) with 54 articles scoring 0 for AAS. The article with the highest AAS was (Perioperative Safety in the Longitudinal Assessment of Bariatric Surgery). The USA had the most articles in the top 10 AAS with 5 publications. 93 papers dealt with complications of LAGB making this the most extensively studied topic in this review followed by weight loss which was investigated in 93 papers (Table 5). Long term prognosis or outcomes following LAGB was the least discussed topic with only 4 articles dealing with this topic.

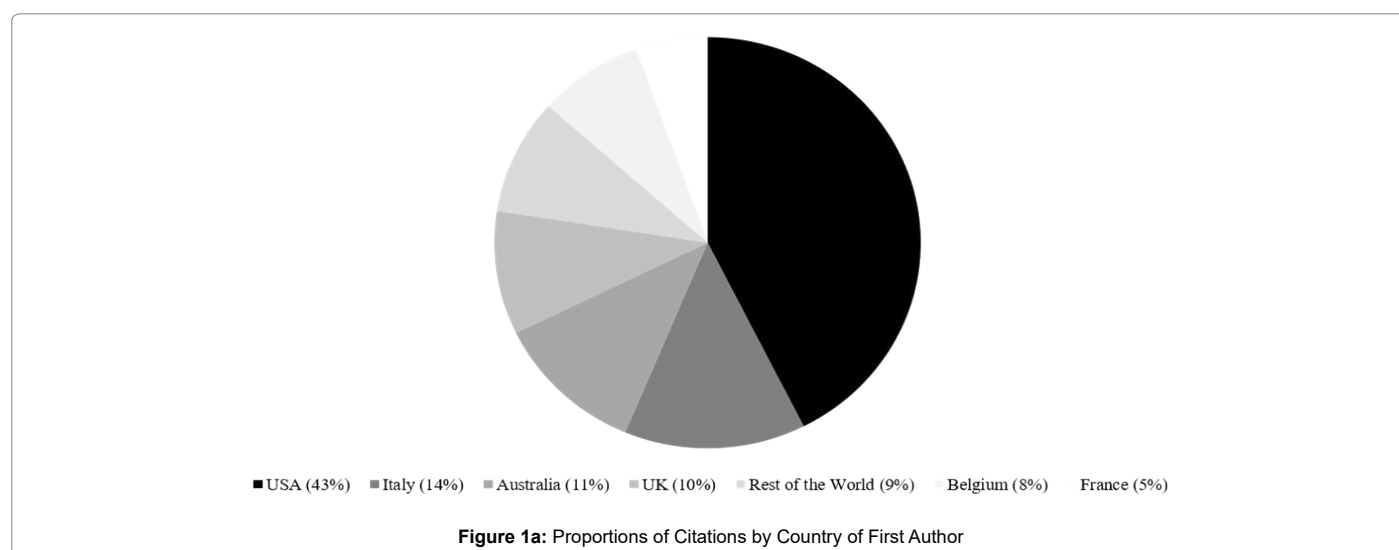
Evidence levels for the top 100 articles were scored using the Oxford Evidence Based scoring system [11]. 14 papers were classed as providing level 1 evidence, 4 papers were level 2 evidences and level 3 evidences each, 62 papers were level 4 evidence and 16 papers were level 5 evidence. There was a statistically significant difference between the LOE and TCC (p=0.0029) (Figure 2a). The median number of citations received at each evidence level was level 1 165 (IQR 115.25-606.25), level 2 460 (IQR 292.25-434), level 3 190.5 (IQR 100.75-287.5), level 4 112 (IQR 89.25-177.25) and level 5 126 (IQR 103.25-227.5). There was a statistically significant difference between LOE and CRI (p=0.00002, Figure 2b). The median CRI at each evidence level was level 1 18.75 (IQR 13.75-49.75), level 2 3.05 (IQR 26.51-38.54), level 3 16.30 (IQR 6.92-41.02), level 4 7.18 (IQR 5.88-12.37) and level 5 13.33 (IQR 8.90-21.51). There was also a statistically significant difference between LOE and the AAS (p=0.00173, Figure 2c). The median AAS received at each evidence level was level 1 26 (IQR 6.5-43), level 2 8.5 (IQR 0.75-20), level 3 1.5 (IQR 0-14.5), level 4 0 (IQR 0-3.75) and level 5 0 (IQR 0-1).

Articles published from the year 2006 onwards had a significantly higher AAS compared to articles published prior to 2006 with median of 5.5 (IQR 0-23.25) and 0 (IQR 0-0) respectively (p = 0.00001) (Figure 3). The AAS of articles which were published both prior to 2006 did not have a significant correlation with the TCC (r = 0.2332, p = 0.1108) (Figure 4a) but was positively correlated with the CRI (r = 0.3194, p = 0.0268) (Figure 5a). The AAS of articles which were published following 2006 did not have a significant correlation with either the TCC (r = 0.5274, p = 5.8596, Figure 4b) or the CRI (r = 0.5274, p = 5.8596) (Figure 5b).

Journal Title	Impact factor (2018)	Number of articles in the top 100	Total number of citations
American Journal of Gastroenterology	10.24	1	121
American Journal of Surgery	2.2	5	581
Annals of internal medicine	19.32	1	962
Annals of Surgery	9.48	10	1678
Annual Review of Medicine	9.5	1	255
Archives of Surgery	-	1	219
Diabetes Care	13.4	2	314
Gastroenterology	19.23	1	250
Health Technology Assessment	3.9	1	551
International Journal of Gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics	1.67	1	84
Journal of Clinical Endocrinology and Metabolism	5.61	1	139
Journal of Laparoendoscopic Advanced Surgical Techniques. Part A	1.32	2	185
Journal of the American College of Surgeons	4.45	3	320
Journal of Pediatric Surgery	2.1	1	79
Journal of the American Medical Association	51.27	4	2260
Journal of the American Medical Association – Pediatrics	12	1	139
Medical Care	3.8	1	98
Microbiology	1.03	1	83
Nature Reviews: Gastroenterology and Hepatology	23.57	1	83
New England Journal of Medicine	70.67	1	877
Obesity Surgery	3.6	36	5633
Surgery for Obesity and Related Diseases: Official Journal for the American Society for Bariatric Surgery	3.16	7	462
Surgery Today	2.08	1	92
Surgical Endoscopy	3.21	10	1462
The American Journal of Medicine	4.76	1	310
The British Journal of Surgery	5.57	1	241
The Cochrane Database of Systematic Reviews	7.76	3	1197
World Journal of Surgery	2.77	1	192

**Abbreviation:** <sup>1</sup>LAGB = Laparoscopic Adjustable Gastric Banding

**Table 2:** Journals with the top 100 most cited LAGB<sup>1</sup> articles.



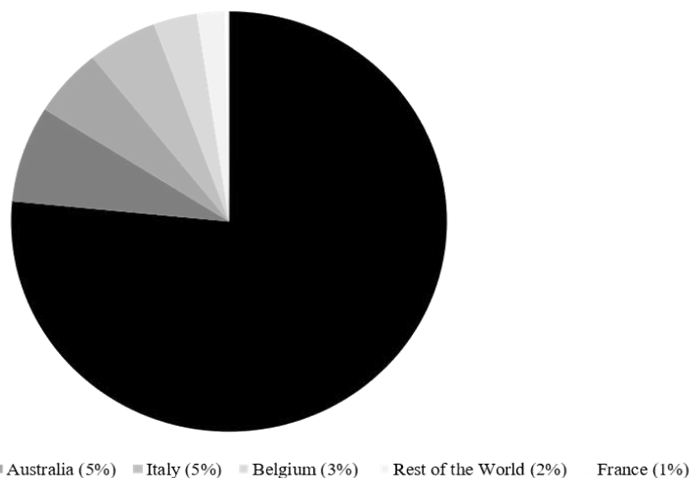


Figure 1b: Proportion of AAS by Country of First Author.

Rank	Citation rate	Journal	First author	Senior author	Title	Institution (first author)	Country
1	187.5	Obesity Surgery	Angrisani, L	Scopinaro, N	Bariatric Surgery Worldwide 2013	University of Genoa	Italy
2	135.6	The Cochrane Database of Systematic Reviews	Colquitt, J.L	Frampton, G.K	Surgery for Weight Loss in Adults	University of Southampton	UK
3	123.5	Obesity Surgery	Angrisani, L	Scopinaro, N	Bariatric Surgery and Endoluminal Procedures: IFSO Worldwide Survey 2014	University of Genoa	Italy
4	110.332	Journal of the American Medical Association	Chang, S	Colditz, G.A	The Effectiveness and risks of Bariatric Surgery An Updated Systematic Review and Meta-analysis, 2003-2012	Washington University	USA
5	87.7	University of Washington	Flum, D.R	Yanovski, S.Z	Perioperative Safety in the Longitudinal Assessment of Bariatric Surgery	National Institute of Diabetes and Digestive and Kidney Diseases	USA
6	77.917	Journal of the American Medical Association	Dixon, J	Anderson, M	Adjustable gastric banding and conventional therapy for type 2 diabetes - A randomized controlled trial	Monash University	Australia
7	64.132	Annals of Internal Medicine	Maggard, M	Shekelle, P.G	Meta-analysis: Surgical Treatment of Obesity	Southern California Evidence-Based Practice Center	USA
8	55.1	Health Technology Assessment	Picot, J	Clegg, A.J	The clinical effectiveness and cost-effectiveness of bariatric (weight loss) surgery for obesity: a systematic review and economic evaluation	University of Southampton, UK.	UK
9	46.429	Annals of Surgery	O'Brien, P.E	Brown, W.A	Long-Term Outcomes After Bariatric Surgery Fifteen-Year Follow-Up of Adjustable Gastric Banding and a Systematic Review of the Bariatric Surgical Literature	Monash University	Australia
10	35.908	The Cochrane Database of Systematic Reviews	Colquitt, J.L	Clegg, A.J	Surgery for obesity	University of Southampton	UK

Abbreviation: 'CRI = Citation Rate Index'

Table 3: Top 10 articles with the highest CRI<sup>1</sup>.

Rank	AAS	First author	Senior author	Title	Institution (first author)	Country
1	413	Flum, D.R	Yanovski, S.Z	Perioperative Safety in the Longitudinal Assessment of Bariatric Surgery.	University of Washington	USA
2	382	Encinosa, W.E	Steiner, C.A	Recent Improvements in Bariatric Surgery Outcomes	Center for Delivery, Organization, and Markets, Agency for Healthcare Research and Quality, USA	USA
3	139	Chang, S	Colditz, G.A	The Effectiveness and Risks of Bariatric Surgery An Updated Systematic Review and Meta-analysis, 2003-2012	Washington University	USA

4	132	Inge, T.H	Buncher, C.R	Perioperative Outcomes of Adolescents Undergoing Bariatric Surgery The Teen-Longitudinal Assessment of Bariatric Surgery (Teen-LABS) Study	Cincinnati Children's Hospital Medical Center	USA
5	94	Nguyen, N.T	Varela, J.E	Bariatric surgery for obesity and metabolic disorders: state of the art	University of California	USA
6	66	Colquitt, J.L	Frampton, G.K	Surgery for Weight Loss in Adults	University of Southampton	UK
7	49	Himpens, J	Dapri, G	Long-term Outcomes of Laparoscopic Adjustable Gastric Banding	Saint Pierre University Hospital	Belgium
8	44	Dixon, J	Anderson, M	Adjustable gastric banding and conventional therapy for type 2 diabetes - A randomized controlled trial	Monash University	Australia
9	40	O'Brien, P.E	Brown, W	Long-Term Outcomes After Bariatric Surgery Fifteen-Year Follow-Up of Adjustable Gastric Banding and a Systematic Review of the Bariatric Surgical Literature	Monash University	Australia
10	33	Angrisani, L	Scopinaro, N	Bariatric Surgery Worldwide 2013	General and Endoscopic Surgery Unit Bosco Hospital	Italy

Abbreviation: <sup>1</sup>AAS = Altmetric Attention Score

Table 4: Top 10 articles with the highest AAS<sup>1</sup>.

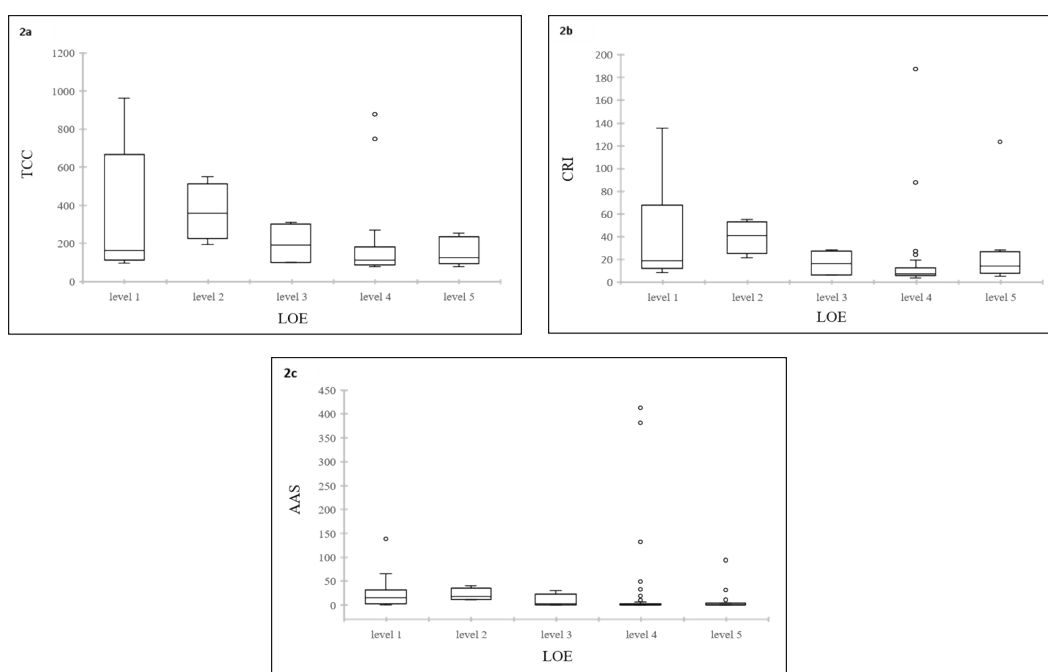


Figure 2: Relationship between Level of Evidence (LOE), Total Citation Count (TCC), Citation Rate Index (CRI) and Altmetric Attention Score (AAS). LOE has a statistically significant association with TCC ( $p=0.0029$ , Figure 2a), CRI ( $p=0.00002$ , Figure 2b) and the AAS ( $p=0.00173$ , Figure 2c) Kruskal–Wallis Test.

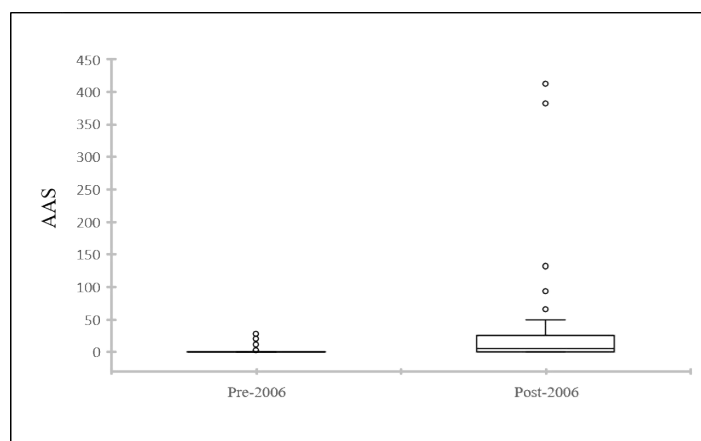
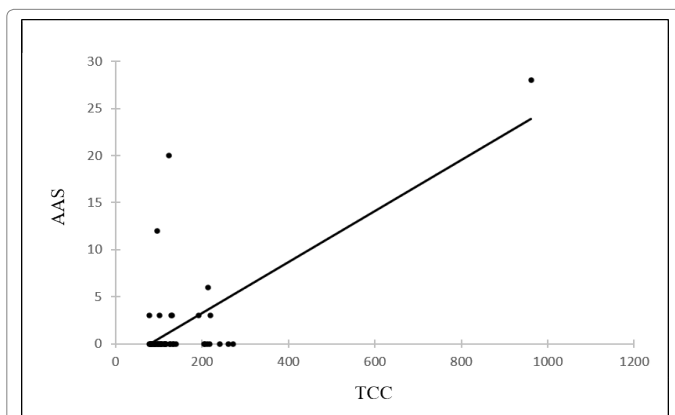
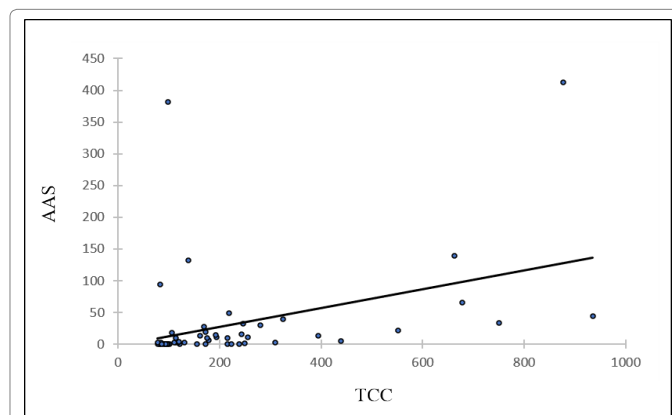


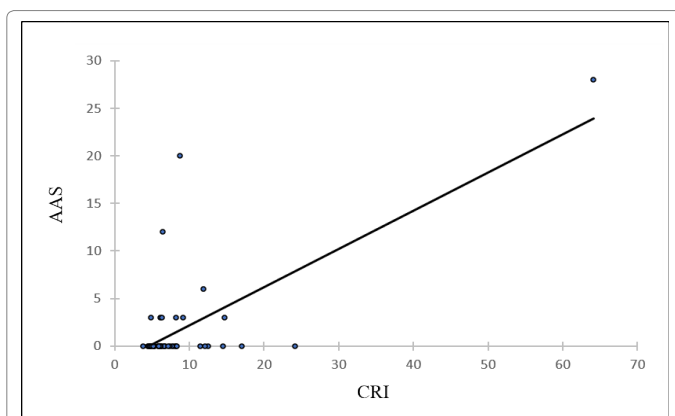
Figure 3: Distribution of Altmetric Attention Scores (AAS) in articles published pre-2006 and post-2006 ( $p=0.00001$ ) - Kruskal–Wallis test.



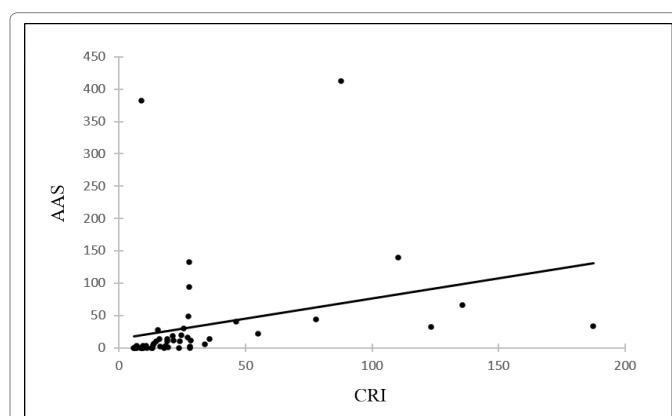
**Figure 4a:** Relationship between Altmetric Attenuation Score (AAS) and Total Citation Count (TCC) Pre-2006 Spearman Rank Correlation test  $r=0.2332$   $p=0.1108$ .



**Figure 4b:** Relationship between Altmetric Attenuation Score (AAS) and Total Citation Count (TCC) Post-2006, Spearman Rank Correlation test  $r=0.5274$   $p=5.8596$ .



**Figure 5a:** Relationship between Altmetric Attenuation Scores (AAS) and Citation Rate Index (CRI) Pre-2006 Spearman Rank Correlation test  $r=0.3194$   $p=0.0268$ .



**Figure 5b:** Relationship between Altmetric Attenuation Score (AAS) and Citation Rate Index (CRI) Post-2006 Spearman Rank Correlation test  $r=0.5274$   $p=5.8596$ .

S. No	Topic / Subject area	Number of papers
1	Complications	93
2	Weight Loss	91
3	Improvement of Co-morbidities	69
4	Indications	43
5	Long Term Prognosis or Outcomes	4

**Table 5:** Most frequently referenced topics.

## Discussion

Bariatric Surgery is now well established as an effective treatment for morbid obesity and associated co-morbidities [110]. However, there is still ongoing debate regarding the exact indications for different bariatric operations and their long term outcomes. LAGB is one of the most widely used procedures worldwide for the treatment of morbid obesity [1]. There has been widespread interest in recent years regarding LAGB and, in particular, the indications, weight loss results, effect on co-morbidities, complications and long-term results following LAGB. It is therefore, not surprising, that the four most widely studied topics amongst the top 100 articles featured in this review include complications, weight loss, improvement of co-morbidities and indications of LAGB. This highlights that a bibliometric analysis is a very useful way to ascertain the most relevant and important topics

in an area of interest as well as providing the interested reader with a ready reckoner of the most influential manuscripts in that setting.

The traditional gold standard for assessing the impact of a published manuscript has been the TCC whilst an important measure of the quality of the research is the LOE it provides. Hence, bibliometrics which utilises these metrics for analysis and comparison is considered to be a very useful tool. Our study has shown a significant difference between the LOE and TCC as well as CRI. Studies with level 1 & 2 evidences have overall higher TCC and CRI compared to studies with level 4 & 5 evidences. Whilst this is not unexpected, it does demonstrate that TCC and CRI are both useful metrics to assess academic impact and studies with superior evidence quality attract more citations. In contrast, Powell et al. did not note any correlation between LOE and TCC in their study and noted that

this was a surprising result in their opinion. They attributed this to the challenges inherent in linking impact with citation and research quality but an alternative explanation could be the lead time bias inherent in measuring citation count [111].

An interesting finding of this study is that 89 of the 100 articles in this study have been published since 2000. This is perhaps not surprising because surgery for morbid obesity is still a field in its relative infancy and indeed most of the major developments have taken place during this century. However, the relatively short time period that spans most of the articles in this study makes this study uniquely robust in assessing the utility of AAS as an alternative index to other bibliometric indices. All the studies comparing bibliometric indices and AAS so far have been limited by the fact that a significant proportion of their articles were published before 2000 and, therefore, inherently biased against AAS as a measure of impact. This bias arises because most social media and other platforms included in the AAS scoring algorithm have evolved after 2000 such as Twitter in 2006 and Mendeley in 2007. In fact, our study demonstrates this bias clearly and shows a significantly lower AAS for articles published pre-2006 compared with articles post-2006. Our study also shows that AAS correlates with LOE in a trend that is similar to TCC and CRI. This shows that AAS can be used as an alternative index to citation count and CRI as a measure of article impact. Previous studies have also demonstrated correlation between AAS and TCC [112]. Another finding that supports the credibility of AAS as an alternative metric to TCC and CRI is the fact that 60% of the publications all three lists of top 10 articles ranked on basis of the highest number of citations, CRIs and ASS were the same [Tables 1, 3 & 4].

Another interesting finding of note is that there is no significant difference in the association between AAS and TCC or CRI in post-2006 articles (Figure 4a and 5a) suggesting that perhaps CRI is a redundant index and that TCC alone should suffice. However, in pre-2006 papers AAS is significantly correlated with CRI but not TCC (Figure 4b and 5b). The explanation of this perhaps lies in the phenomenon of lead-time bias or, more accurately, the lack of it in the post-2006 articles in this study. It is likely that articles published early in the 2006-2020 period have not had sufficient time to accrue enough citations compared to articles published more recently to generate a lead-time bias. It is likely that if this study is repeated after a decade or two, then divergent results will be noted between TCC and CRI in the post-2006 cohort.

This study has some limitations due to deficiencies intrinsic to the chosen study design as well as weaknesses inherent in the bibliometric indices. Firstly, citation counts and CRI are influenced by several types of bias such as language bias, institutional bias, and publication bias amongst others. In this study the language bias resulted in high numbers of English speaking countries being represented, particularly publications from USA which has been seen previously [111,113]. Secondly, the search strategy used to identify the top 100 articles invariably includes articles that are not relevant and can also exclude high impact articles. We noted that our search strategy included 4 articles that were eventually considered as being not relevant. Thirdly, as discussed earlier, the use of AAS as a metric is biased by the fact that articles published prior to early 2000s are significantly under-represented in social media and other online platforms used to calculate the AAS. Finally, a top 100 analysis invariably limits the total data points available for analysis across different sub-groups to exactly 100 and the statistical results should be interpreted whilst bearing this in mind.

## Conclusion

By analyzing the most influential articles that have shaped our understanding of LAGB, this study serves as a reference of the highest impact articles that have shaped the role of LAGB as an operation for morbid obesity whilst also serving as a guide for future research. Our study shows that AAS is a valid metric for assessing the impact of a study along with traditional metrics such as TCC and CRI. However, AAS is not reliable for articles published before 2006. Furthermore, the LOE of a study is significantly associated with all three indices of study impact including TCC, CRI and AAS.

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