Empirical validity of Lotka's Law in Heart Transplantation research published in the Journal of Heart and Lung Transplantation (JHLT)

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Abstract

The study validated Lotka's law of scientific productivity in heart transplantation research, published in the Journal of Heart and Lung Transplant (JHLT), using data from the Web of Science, including 9296 articles. Various scientometric tools were employed, revealing a close fit of Lotka's law to JHLT publications through the inverse-square method, with values of 'n' (-1.8794), 'c' (0.6029), and CV (0.009725). The authors' productivity frequency slightly exceeded the determined Dmax value (0.6243) and K-S test (0.009725). The Chi-square test yielded a significant p-value of 93.446, which was lower than the tabular value of 143.94, confirming that the heart transplantation publications fit Lotka's law effectively.

Keywords
Heart transplantation; Journal of Heart and Lung Transplantation; Scientific productivity
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1. Introduction

Due to steady population growth and the adoption of a modern lifestyle, there is an increased risk of heart disease and heart failure. It includes unhealthy diet, physical inactivity, smoking, heavy alcoholism, along with medical conditions such as mental stress, hypertension, diabetes, high blood pressure, high cholesterol, obesity and so on. Of these reasons, the heart can be damaged, and heart failure may occur. When the heart is severely damaged and fails to respond to other medical treatments, a heart transplant is the only treatment to save the patient at the end stage of life. Heart transplantation is a process of replacing a damaged heart or diseased heart with a healthier heart. It is the preferred clinical treatment for a specific patient with advanced heart failure to maximise survival and improve quality of life.

Heart transplantation is one of the most significant milestones in medical history. The announcement of '*Transplanted heart is beating, many problems to be answered'* was the headline of 'The Star' Newspaper, which gave hope to the millions of sick or downcast hearts. It was after the successful completion of the world's first human heart transplant on patient *Louis Washkansky* at Groote Schuur Hospital in Cape Town, performed by Christian Barnard in 1967. Recently, surgeons of Duke University have successfully transplanted a revived "dead" heart into a three-month-old baby by using the innovative technique called "on-table reanimation", which involves a customized machine to revive the donor heart outside the donor's body. The World Health Organisation (WHO) statistics say that Heart (Cardiovascular) disease is one of the dominant causes of death in the world, resulting in 16% of the total deaths globally as of 2019. With the evolution of medicine and clinical practices, the causes and growth of various heart diseases have also been steadily discovered. Heart transplants are the only option in cases of failing blood circulation or heart failure. (Shang et al., 2025). The National Organ and Tissue Transplant Organisation (National Organ and Tissue Transplant Organization: Ministry of Health and Family Welfare, 2024) reported that India has ranked third in the world, after the United States and China, in organ and tissue transplantation. India's number of transplants increased significantly from 4,990 in 2013 to 18,378 in 2023, and 19,011 transplants were performed in 2024. A total of 253 heart transplants were performed in India; still, over

63000 kidney transplants and 22000 liver transplants are needed in the present scenario.

Scientometrics is the scientific mapping of academic knowledge and contributions within a specific domain, using statistical tools and indicators to identify trends and growth in the subject. Scientometrics laws are used to evaluate and test the trend of the subject. These laws help researchers, librarians, and scientists measure, analyse and understand the patterns of the subject. One among those laws is Lotka's Law of Scientific Productivity, which Alfred James Lotka originated. This law has become widely tested and accepted by scholars across various domains. The Lotka's law states the frequency of scientific publications by authors in each field. Lotka's law(Lotka, 1926) can be explained as follows: out of all the authors in a specific field, 60% of the authors will contribute only one publication each, 15% of the authors will contribute two publications each, 7% of the authors will contribute three publications each, and only 6% of authors will contribute up to ten publications each(Sahu & Jena, 2022).

2. About Journal of Heart and Lung Transplantation (JHLT)

The Journal of Heart and Lung Transplantation is the official publication of the International Society for Heart and Lung Transplantation (JHLT, 2025). It was established in the year 1981, titled "Heart Transplantation"; later in the year 1991, it was renamed to its current title. The JHLT focuses on advanced heart and lung diseases, heart and lung transplantation, lung failure therapies, mechanical circulatory support, advanced lung disease, pulmonary vascular disease, cell replacement therapy, and preclinical translational research. It has an impact factor of 7.865 and is ranked 1st of 26 Journals in the Transplantation category and 4th out of 204 journals in the Surgery category. The JHLT is indexed in Scopus, Medline, Science Citation Index Expanded (SCIE), SCImago Journal Rank, and SNIP.

3. Background Studies

Several studies have tested Lotka's law for the scientific productivity of a specific journal. Barik and Jena (2020) examine the applicability of Lotka's inverse law for selected LIS open-access journals. The results of the study did not meet the expected value, with a computed value of n = 2.693, and they also show a significant difference in the Chi-square test. Hence, no significant expected values were found for the observed value, which obviously does not fit Lotka's Law. (Barik & Jena, 2020). Thamaraiselvi, Lakshmi, and Manthiramoorthi (2020) conducted a study to verify the applicability of Lotka's law to the published articles in the Current Science Journal, indexed in the Web of Science Core Collection. A total of 4290 articles by 777 authors were published. The values of *'n', 'c'* and the *critical value (CV)* are 0.14, 0.058 and 0.0585, respectively. As a result, the study examined Lotka's law and found that it did not fit the data presented in the Current Science Journal *(Thamaraiselvi et al., 2020)*. Dandge & Sonwane (2023) A total of 1753 articles were selected from the Journal of Energy and Environmental Science and examined with Lotka's inverse law. As a result, a 0.65 degree of collaboration was identified, which clearly reflects the dominance of multiple-authored contributions. The Dmax (0.0356) and Chi-square (0.0389) values were identified and evaluated, indicating that the Dmax is lower than the Chi-square. It was confirmed that Lotka's law fits the JEES.

4. Objectives of the Study

The main objectives of the study are as follows.

1. To provide an overview of the coverage and statistical distribution of the heart transplantation research in JHLT.
2. To highlight the metrics of the top influential and productive authors
3. To investigate the applicability of Lotka's law to authors of heart transplantation research published in JHLT
4. To examine and evaluate the significance of Lotka's inverse power law by applying the Chi-Square and the K-S Goodness-of-fit test.

5. Scope and Limitations of the Study

The Journal of Heart and Lung Transplantation (JHLT) has published 9,296 articles and is recognized as a leading journal in the field of heart transplantation. It has contributed significantly and ranked 1st in the field of heart transplantation literature. The journal received 129,600 citations for 3,596 articles, averaging 36.00 citations per article during the study period from 1994 to 2023 (Lakshminarasimhappa, 2025). Hence, the study selected this journal to test Lotka's law. Lotka's law

examines the frequency of contributors and identifies the applicability of the inverse-square pattern of research productivity to the JHLT. It enables readers to understand the dominance in research output, authorship patterns, potential reviewers, and highlights emerging contributors in heart transplantation research in JHLT. The study helps evaluate the emerging research area by revealing the maturity of the subject.

The study is limited to the 'Web of Science' database, which is one of the leading abstracting and citation databases; the database includes a broader range of medical publications from vendors globally. The Journal of Heart and Lung Transplantation is indexed in the Web of Science core database, making it suitable for data collection and the conduct of this study.

6. Methodology

The Web of Science Core Collection was selected to retrieve data on heart transplantation research, and publication titles were limited to The Journal of Heart and Lung Transplantation. This journal has been indexed from 1991 to the present, and a total of 9,296 articles (as of November 9, 2025) were found for heart transplantation research. The researcher used the "Query builder and exact phrase search" as an advanced search strategy which reflects as (((TI=(heart transplant*)) OR TI=(heart-transplant*)) OR TI=(cardiac transplant*)) OR TI=(cardiac-transplant*) and Heart Transplantation (OR – Search within topic) and Heart Transplant (OR – Search within topic) and Pediatric Heart Transplant (OR – Search within topic) and Pediatric Heart (OR – Search within topic) and Pediatric Heart Transplantation (OR – Search within topic) and JOURNAL OF HEART AND LUNG TRANSPLANTATION (Publication Titles). After collecting the data, the researcher utilised RStudio, Biblioshiny, VOSviewer, and MS Excel for data analysis and tabulation, presenting the results in tables and figures.

7. Data Analysis and Interpretation

7.1. Main Information of the Data

Figure 1 presents an overview of the Journal of Heart and Lung Transplantation and its coverage of heart transplantation research publications, which identified 9,296 articles contributed by 28,040 authors. The data reflect 137 single-authored documents, and 809 (8.7%) of articles were contributed by multiple authors. Table 1 denotes the annual growth of 464 (4.99%) in heart transplantation research published in the JHLT. It reflects that the contribution to heart transplantation research seems to have a stable upward trend in annual publications. The journal began publishing with 103 articles and has since reached an annual total of 540 articles on heart transplantation research.



Figure 1 Coverage of Journal of Heart and Lung Transplantation

Table 1: Annual Growth of Heart Transplantation Research in JHLT

Year	Articles	Year	Article
1991	103	2009	327
1992	168	2010	286
1993	137	2011	301
1994	105	2012	311
1995	108	2013	295
1996	99	2014	302
1997	93	2015	330
1998	90	2016	369
1999	84	2017	379
2000	95	2018	409
2001	99	2019	373
2002	82	2020	441
2003	105	2021	475
2004	137	2022	487
2005	317	2023	490
2006	263	2024	502
2007	315	2025	540
2008	279	**Total**	**9296**

1.1. Most productive and highly impacted authors

Table 2 presents the most significant authors who contributed the most articles and the most impactful authors in the field of heart transplantation research in JHLT. Out of 9296 articles, 24.39% (2267) were published by the top ten prolific authors. Of these, Patel J contributed 349 most significant articles and ranked 1st among the others. Followed by Kittleson, M, and Kobashigawa ranked 2nd and 3rd, respectively. In contrast, Stehlik Joseph is indeed a highly impactful author, with 16,073 citations since he published registry reports in JHLT, which can be considered a foundation for heart transplantation research. Stehlik published articles related to clinical trials and policy, which were cited by clinical practitioners and medical researchers. Following Edward, LB has 10,814 articles, having co-authored registry reports and numerous clinical papers. Kucheryavaya AY has received 10,054 citations for 88, ranking in third place and being highlighted as one of the most influential and frequently cited authors. The author served as a co-author on multiple registry reports and significant articles.

Table 2: Most productive and highly impacted authors

Authors with the Highest articles		Highly Impacted Authors		
Author	**No of Documents**	**Author**	**No of Documents**	**Citations**
Patel, J	349	Stehlik, J	240	16073
Kittleson, M	290	Edwards, LB	88	10814
Kobashigawa, J	289	Kucheryavaya, AY	57	10054
Czer, L	252	Dobbels, F	58	9435
Stehlik, J	240	Meiser, B	66	8359
Kobashigawa, JA	210	Kobashigawa, J	289	7600
Uriel, N	183	Kirk, R	67	7359
Esmailian, F	157	Zuckermann, A	141	6968
Naka, Y	156	Christie, JD	37	6816
Zuckermann, A	141	Benden, C	35	6662

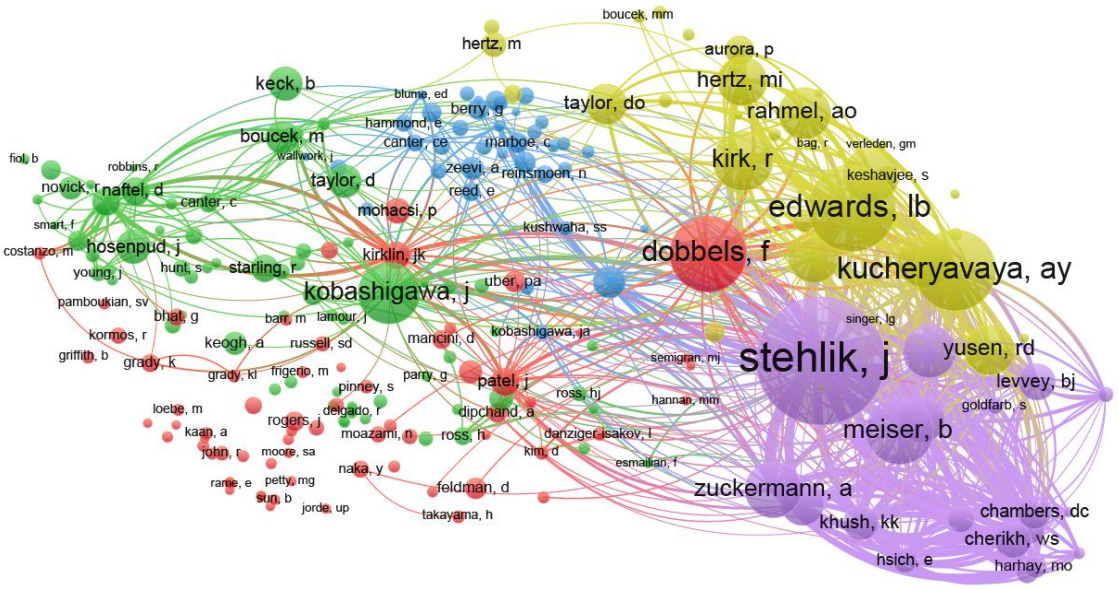


Figure 2 Visualisation of the most cited authors in heart transplantation research

Figure 1

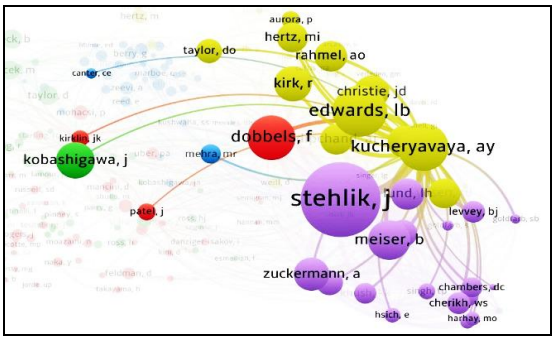


Figure 2

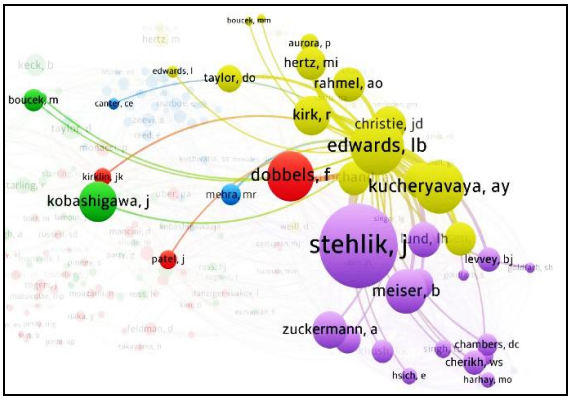


Figure 3

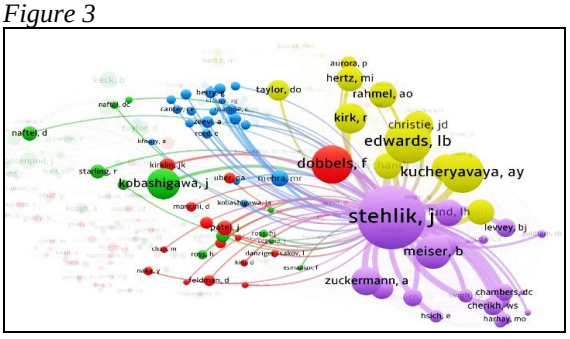


Figure 4

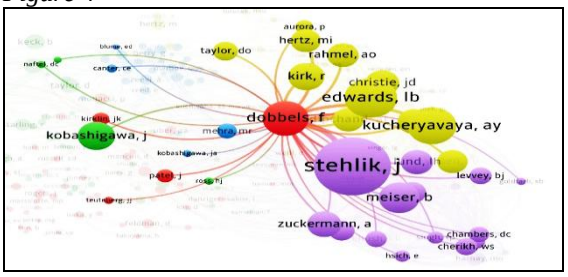


Figure 1 to 4 represents the strong citation network of the most impactful authors (Figure1-Stehlik; Figure2-Edwards; Figure3-Kucheryavaya; and Dobbels)

1.1. Lotka's law of scientific productivity

The study applied Lotka's Law to heart transplantation research published in JHLT, revealing the authorship pattern and the research's significant contributions. Table 3 presents the article/s written by the frequency author/s, the proportion of authors and the expected frequency distribution of authors. It indicated that 17617 (62.83%) authors published 1 article, whereas the expected proportion is 61.20, as identified in the tabulation. This clearly indicates a 1.63% difference in frequency distribution, which is very close to Lotka's law of conformity. Likewise, two articles accounted for 4349 (15.51%) of the authors, which is very close to the expected distribution (15.30%). Three and four articles were published by 1809 (6.451%) and 1004 (3.581%), which are close to the expected proportion of the inverse law. The table shows that the proportion of written documents by authors is almost equal to the expected value of Lotka's law. The study reveals that the field's scope is broad, and that highly prolific authors appear to be more selective.

Table 3 Author productivity through Lotka's Law

Document Written	Proportion of Authors	Proportion of Authors (%)	Lotka's Law (%)
1	17617	62.828	61.200
2	4349	15.510	15.300
3	1809	6.451	6.800
4	1004	3.581	3.825
5	661	2.357	2.448
6	432	1.541	1.700
7	361	1.287	1.249
8	269	0.959	0.956
9	204	0.728	0.756
10	163	0.581	0.612
11	115	0.410	0.506
12	105	0.374	0.425
13	94	0.335	0.362
14	78	0.278	0.312
15	54	0.193	0.272
16	57	0.203	0.239
17	58	0.207	0.212
18	48	0.171	0.189
19	22	0.078	0.170
20	40	0.143	0.153
21 to 345	**500**	**1.783**	**2.314**
	28040	**100.00**	**100.00**

To strengthen and validate Lotka's law, Nicholls recommends calculating the values of 'n', 'C', and 'Critical Value' (CV). The process requires identifying the value of exponent 'n'. The linear least squares method was used to identify the value of 'n' from the following equation:

$$n=\frac{N\sum XY-\sum X\sum Y}{N\sum X^2-(\sum X)^2}$$

Where:
N Number of sample data (data set)
X=logarithm of papers/articles x; and
Y= logarithm of authors y.

$$n=\frac{107 \times 103.425 - 177.492 \times 88.030}{107 \times 317.090 - (177.492)^2}$$

$$n=\frac{11066.48044 - 15624.54476}{33928.64573 - 31503.33841}$$

$$n=\frac{-4558.1}{2425.30731}$$

n= -1.8794

To identify the value of 'C' inversion of the Riemann Zeta function is used as below

$$C=\frac{1}{\sum_1^{p-1}\frac{1}{x^n}+\frac{1}{(n-1)(p^{n-1})}+\frac{1}{2p^n}+\frac{1}{24(p-1)^{n-1}}}$$

Where,
p= sample size – 107
p-1=106
x=number of contributions = 1, 2, 3, 4, 5…….in the table.
Using the defined values, we calculated as below

$$C=\frac{1}{1.6398+\frac{1}{(1.8794-1)\left(107^{1.8794}\right)}+\frac{1}{2\left(107^{1.8794}\right)}+\frac{1}{24(106)^{2.8794}}}$$

$$C=\frac{1}{1.6398+0.018674+0.00007627+0.0000000614}$$

$$C=\frac{1}{1.6586}$$

C=0.6029361

1.1.1. Kolmogorov-Smirnov (K-S) test

The Kolmogorov-Smirnov (K-S) test examines the goodness of fit between expected author productivity and the theoretical Lotka distribution(Pao, 1979). To evaluate the conformity of Lotka's Law in heart transplantation research, the proportional value of the minimum discrepancy D_{max} and CV should be examined**.** However, the critical value (CV) was determined to be at the 0.01 significance level. The proportional value of D_{max} is 0.6243, indicating a slight deviation that aids in calculating the CV.

$$CV=\frac{1.63}{[\sum yx+(\frac{\sum yx}{10})^{\frac{1}{2}}]^{1/2}}$$

$$CV=\frac{1.63}{[28040+(\frac{28040}{10})^{\frac{1}{2}}]^{1/2}}$$

$$CV=\frac{1.63}{[28040+(2804)^{\frac{1}{2}}]^{1/2}}$$

$$CV=\frac{1.63}{[28040+52.95]^{1/2}}$$

$$CV=\frac{1.63}{[28092.95]^{1/2}}$$

$$CV=\frac{1.63}{167.60952}=0.009725$$

Critical Value (CV) = 0.009725

D_{max} 0.6243> CV 0.009725 = does not confirm Lotka's law

Since the D_{max} value (0.6243) is greater than the K-S Critical value (0.009725), it validates rejection of Lotka's law. Hence, the Chi-square test is used to validate the discrepancy between actual and expected results.

1.1.2. Chi-square testing of Heart transplantation research

The Chi-square test is used to strengthen the law. The chi-square test provides an objective measure of goodness of fit, along with a corresponding probability value to interpret the result. The study was calculated using below equation;

Chi-Square $X^2=\sum (Fi-Pi)^2/Pi$
Fi = Observed number of authors
Pi = Expected number of authors

Hence, the value of $X^2=\sum (Fi-Pi)^2/Pi$ is calculated **93.446**

Now, the tabular value of the significance level of 0.01 was identified using the Chi-square distribution table, and it was **143.9400159.**

Hence, from the Chi-square test, the calculated value is less than the tabular value, indicating a significant result, and the data on heart transplantation research published in the JHLT fit Lotka's law of Scientific Productivity.

8. Findings and Conclusion

The Journal of Heart and Lung Transplantation is one of the leading journals in coverage of heart transplantation research. The study analysed the productivity of authors in heart transplantation research published in the JHLT, which denotes that the number of prolific authors publishing n articles/papers is proportional to $1/n^2$ of those publishing a single article. The analysed data reflected the empirical author-frequency distribution, which shows a typical inverse relationship, with a small number of authors accounting for a large number of publications (20 articles were accounted for by 0.143 (40) authors). In contrast, the majority produced only one article (published by 62.828% of authors) or two articles (published by 15.51% of authors). The examined values demonstrated conformity with Lotka's law, as the calculated value (93.446 of x^2) is less than the tabular value (143.94**)**, indicating that the scholarly publications on heart transplantation research in JHLT followed a high standard scientific distribution.

9. Conclusion

The present study tested the validity of Lotka's law by showing that the calculated value is lower than the tabular value. The present study aims to understand and measure the research productivity of researchers in the JHLT and to compare authorship patterns with a global perspective. It helps policymakers and editorial panels by identifying prolific and eminent scholars, plans to deliver a special issue, and fills the gap between submission and the research domain. Furthermore, LIS professionals benefit from identifying core authors and emerging authors in the field of heart transplantation research, which supports collection development. Additionally, it provides cardiologists, surgeons, doctors, researchers, and other medical practitioners with insights into selecting key authors and their impactful contributions to heart transplantation research, which may be adopted in their clinical trials and further research.

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