The 100 most cited articles on lung cancer screening: a bibliometric analysis

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Background: The number of citations of an article reflects its impact on the scientific community. The aim of this study was to identify and characterize the 100 most cited articles on lung cancer screening.

Methods: The 100 most cited articles on lung cancer screening published in all scientific journals were identified using the Web of Science database. Relevant data, including the number of citations, publication year, publishing journal and impact factor (IF), authorship and country of origin, article type and study design, screening modality, and main topic, were collected and analyzed.

Results: The 100 most cited articles were all English and published between 1973 and 2017, with 81 published after 2000. The mean number of citations was 292.90 (range 100–3,910). Sixty articles originated from the United States. These articles were published in 32 journals; there was a statistically significant positive correlation between journal IF and the number of citations (r=0.238, P=0.018). Seventy-nine articles were original research of which 37.9% were about results from randomized controlled trials (RCTs). The most common screening modalities in these articles were low-dose computed tomography (LDCT) (n=78), followed by chest X-ray radiography (CXR) and sputum cytology (n=11). The most common topic in these articles was screening test effectiveness.

Conclusions: Our study presents a detailed list and analysis of the 100 most cited articles published about lung cancer screening which provides insight into the historical developments and key contributions in this field.

Keywords: Lung cancer screening; low-dose computed tomography (LDCT); bibliometric analysis; citations

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Introduction

Lung cancer is the leading cause of cancer death worldwide, causing 24% of all cancer deaths in men and 23% in women (1,2). It is well known that if lung cancer can be treated surgically at an early stage, the prognosis will be significantly improved. However, early-stage lung cancer patients typically are asymptomatic, so that approximately 70% of patients have advanced disease at the time of diagnosis (2). Therefore, many medical and public health institutions have been committed to the early diagnosis and treatment of lung cancer through screening to ultimately thereby reduce deaths from lung cancer.

Since the first publication dedicated to lung cancer screening in 1955 (3), the body of relevant literature in this field has flourished. An evaluation of the most heavily

influential or contributory literature will allow us to better understand the knowledge structure of lung cancer screening. A scientific way to recognize the significance of each article is needed since there are many publications and their quality varies substantially.

Bibliometric analysis is a mathematical and statistical method to estimate how much influence or impact a selected research article has on future research (4,5). The role of bibliometrics in academic medicine is increasing. Among all the bibliometric analyses (5-7), citation analysis is the most widely accepted method and measures the number of times an article has been cited by other articles (8-10). The number of citations of a particular article reflects the impact of that article in a specific scientific field. Therefore, a list of the most highly cited articles can help us to understand the important publishing advancements in one research field.

A very recent bibliometric study for research evaluation purposes was published on lung cancer diagnosis and treatment (11) and showed that significant progress had been achieved for molecular subgroup diagnoses and the matched target therapy in advanced lung cancer. However, to the best of our knowledge, no specific bibliographic analysis about lung cancer screening has been published. The aim of this study was to identify and analyze the characteristics of the 100 most cited articles related to lung cancer screening.

Methods

Ethics committee approval was exempted as this study was a retrospective bibliometric analysis of existing published classical studies.

Identification of the 100 most cited articles

We identified articles through the Web of Science (WOS) database, which is considered one of the most popular and well-established resources for clinical researchers interested in the field of citation analysis (12), in January 2020. Key words included "lung cancer screening", "pulmonary cancer screening", "lung carcinoma screening", and "pulmonary carcinoma screening", with no limitation on time, abstract availability, study type or research subjects. After an extensive search, all the retrieved articles were sorted according to the number of citations. The abstracts or full-texts of all these articles were screened by two reviewers (ML and LZ), and only articles strictly related to the field of lung cancer screening were selected. The articles focused on screening for cancer generally or screening for multiple cancers, including for lung cancer, were also excluded because the citations of these articles may not exactly reflect their influence on the lung cancer screening field.

Article analysis

These articles were analyzed by three reviewers (ML, QC and JWM) who extracted the relevant bibliometric and professional information. For each article, the citation count, language, publication year, journal name along with the latest 2018 journal impact factor (IF) released in 2019, authorship, country of origin, article type and research design of the original study, screening modality focused on by the research, and topic of interest were extracted.

Statistical analysis

The relationship between the IF of a journal and the number of published articles, the IF of a journal and the number of citations of each published article, were analyzed using Pearson correlation. Difference in the publication year of the different screening imaging modalities was compared using Mann-Whitney U test. All analyses were performed by using a statistical software package (SPSS version 21). P values less than 0.05 were considered significant.

Results

The 100 most cited articles regarding lung cancer screening are listed in https://cdn.amegroups.cn/static/application/817dcf099e2d3e0f820d53300b698036/atm-20-3199-1.pdf and are ranked by their number of citations.

Citations

The mean number of citations for the 100 most cited articles was 292.90 (ranging from 100 to 3,910) in total and 23.41 (ranging from 2.42 to 391) per year (https://cdn.amegroups.cn/static/application/817dcf099e2d3e0f820d53300b698036/atm-20-3199-1.pdf). The top 3 cited articles were "Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening" published in the *New England Journal of Medicine* (*NEJM*) in 2011, "Early Lung Cancer Action Project: overall design and findings from baseline screening" published in *Lancet* in 1999, and "Survival of patients with stage I lung cancer detected on CT screening" published in *NEJM* in 2006.

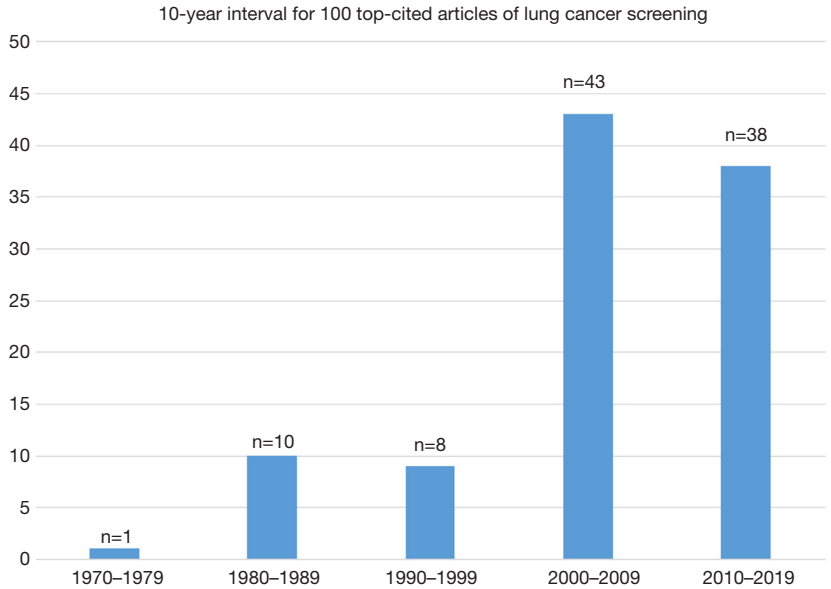

Figure 1 10-year interval for 100 top-cited articles of lung cancer screening.

Language and Year of publication

The top 100 articles were all English and published between 1973 and 2017. *Figure 1* shows a graphical representation of the distribution of the 100 most cited articles by decade of publication. The vast majority (n=81) of articles were published after 2000.

Authorship and countries of origin

The total number of authors for the 100 most cited works was 627. Twenty-three prolific authors contributed more than 5 to 9 articles (*Table 1*). The first authors were from 10 countries with the United States being the most frequent (n=60) (*Table 2*).

Journals

A total of 32 journals published the 100 most cited articles, with 17 journals publishing two or more articles (*Table 3*). The journal with the highest number of articles was *Radiology* (n=13), followed by *Chest* (n=10) and *Lung Cancer* (n=8). The IF of the 32 journals ranged from 1.301 to 223.679. Statistical analysis showed that there was no significant association between journal IF and the number of published articles (r=0.023, P=0.903). There were significant, but weak positive associations between journal IF and total citations of the published article (r=0.238, P=0.018) and citations per year (r=0.288, P=0.004).

Lung cancer screening modality

The most common screening modality studied in these 100 most cited articles was low-dose computed tomography (LDCT) (n=78), and all of these studies were published after 1996. LDCT was followed by chest X-ray radiography (CXR) plus sputum cytology (n=11) or only CXR (n=8), with all of these studies being published before 2011 (*Table 4*) (*Figure 2*). The publication year of the two-imaging modality (LDCT and CXR) was significantly different (P=0.000).

Article type, design and topic

Table 5 summarizes the types of article and study designs of the original studies within the 100 most cited articles. The main topics covered in each article are grouped and outlined in *Table 6*.

Discussion

This study is an interdisciplinary study in bibliometrics and medicine. In order to recognize the key contributions and their influence on lung cancer screening, we presented an accessible list of the 100 landmark articles and offered a

Table 1 Authors that contributed 5 or more articles in 100 most cited articles on lung cancer screening

Author	No. of articles
Berg CD	9
Sone S	9
Henschke CI	8
Jett JR	8
Li F	8
Yankelevitz DF	8
Oudkerk M	7
Church TR	6
de Koning HJ	6
Miettinen OS	6
Smith JP	6
Bach PB	5
Field JK	5
Fontana RS	5
Hasegawa M	5
Maruyama Y	5
Melamed MR	5
Nackaerts K	5
Pedersen JH	5
Riley TL	5
Swensen SJ	5
Takashima S	5
Tammemagi MC	5

Table 2 Countries of origin in the 100 most cited articles on lung cancer screening

Country	No. of articles
United States	60
Japan	10
Netherlands	8
Italy	7
Canada	4
United Kingdom	3
Germany	3
Denmark	3
France	1
Czechoslovakia	1

comprehensive bibliometric and professional analysis.

This bibliometric analysis on publication time showed that the majority (n=80) of the 100 most cited articles were published in this century after 2000, with the earliest article published in 1973. This differs with the bibliometrics published for the whole field of radiology, where the peak time period for the most cited articles was 1990 to 1999 (13-15). However, some subdisciplines depending on advanced radiological techniques, such as CT colonography, oral cone-beam CT and cardiology imaging, show similar peaks after 2000 (16-19). This result suggests that lung cancer screening is still a relatively new field that is evolving rapidly. Our study also showed that 627 authors wrote the 100 most cited articles, and the first authors of 60% of the articles came from institutions in the United States (*Table 2*). This finding reflects the overwhelming influence of the United States on lung cancer screening research.

In the bibliometric analysis of the published journal, the 100 most cited articles were published among 17 different journals, with the top 3 journals being *Radiology*, *Chest* and *Lung Cancer*. The reason why *Radiology* garnered the most publications may be due to the critical role of imaging in lung cancer screening. Although most of these articles are related to imaging, such as CXR and LDCT (n=97), we observed that the top 6 cited lung cancer screening articles were all published in top-tier general medicine journals, such as *NEJM* and *Lancet*. This might be because top-tier general medical journals usually have higher IFs than specialized radiology journals and also have a more influential and broader readership. Furthermore, lung cancer screening is a multidisciplinary topic and therefore is of interest to a general medical audience.

Analysis of the IF was first proposed in 1955 (20) as IF is probably the most widely used indicator for evaluating the influence of journals in various scientific fields as it reflects the average number of citations to recent articles published in that journal. By convention, IF is based on the previous 2 years. Our study showed that journal IF and number of citations had a significant relationship. Overall, this result of lung cancer screening also seems to follow Bradford's law which states that most researchers obtain their citations from a few specific core journals (21). However, the relationship between the number of times cited and journal

Table 3 Journals and their impact factors publishing more than 2 articles in the 100 most cited articles on lung cancer screening

Journal	No. of articles	Impact factor (2018–2019)
Radiology	13	7.608
Chest	10	9.657
Lung Cancer	8	4.599
New England Journal of Medicine	8	70.67
Annals of Internal Medicine	6	19.315
Jama Journal of the American Medical Association	5	51.273
American Journal of Respiratory and Critical Care Medicine/American Review of Respiratory Disease	8	16.494
Cancer	4	6.102
Journal of Thoracic Oncology	4	12.46
Thorax	4	9.64
Lancet Oncology	3	35.386
American Journal of Roentgenology	2	3.161
British Journal of Radiology	2	1.939
International Journal of Cancer	2	4.982
Jama Internal Medicine	2	20.768
Journal of Clinical Oncology	2	28.245
Lancet	2	59.102

Table 4 Main screening method of lung cancer in the 100 most cited articles on lung cancer screening

Main screening modality	No. of articles
Chest X-ray radiography (CXR)	8
CXR + sputum cytology	11
Low-dose computed tomography (LDCT)	78
Blood	3

IF was weak (r=0.238), which may be because the journals that published the 100 most cited articles included articles a wide scope of disciplines including radiology, cancer, chest surgery, respiratory or internal medicine, and general medicine. Also, IF widely differs across different disciplines.

A suitable screening test that can accurately detect lung cancer in earlier stages before a person has any symptoms has been sought after for a long time. Through the top 100 most cited articles, we can see that screening tests for lung cancer include CXR, sputum cytology, blood tests, and LDCT. We demonstrated that the large majority of the top 100 most cited articles focused on LDCT, followed by CXR with sputum cytology, as the screening modality. The CXR and sputum studies which included several famous randomized controlled trials (RCTs) sponsored by the National Cancer Institute (NCI) (22-24), showed that these screening modalities did not reduce mortality from lung cancer, even in high-risk smokers (25-28). After 1996, LDCT, a more sensitive radiographic modality, has been studied widely, as 91.8% articles (78/85) investigated LDCT which reflects that LDCT is currently the only widely recognized test for lung cancer screening. New potential practical screening modalities other than LDCT are still exploratory, including biomarkers from plasma or serum with advances in molecular diagnostics and genomics. These, however, have not been used in clinical practice (29). In our study, only 3 articles were relevant to these screening modalities.

Our analysis revealed that the most cited article on lung cancer screening was the 2011 paper "Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening" published in *NEJM*. This article has been cited

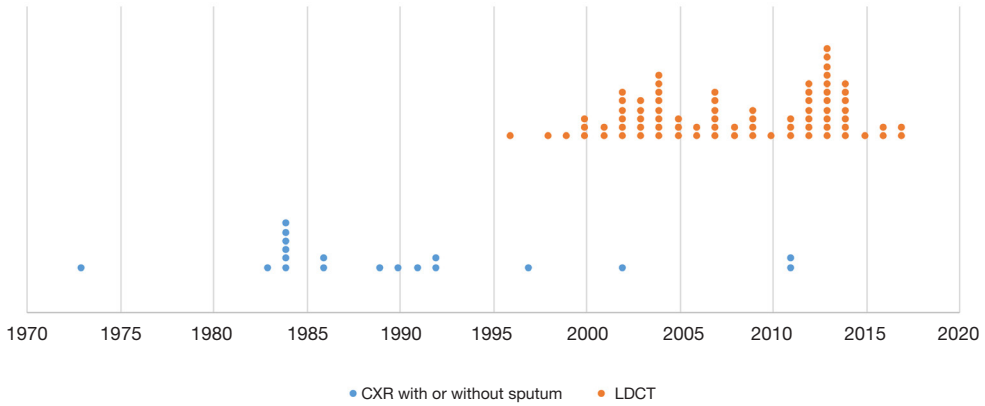

Figure 2 The year distribution of the imaging modality in 100 top cited articles of lung cancer screening.

Table 5 Article type and study design composing the 100 most cited articles on lung cancer screening

Article type	No. of articles
Original article	79
Randomized controlled trial	30
Original prospective	27
Original retrospective	17
Estimate/hypothesis	5
Guideline/consensus/statement	10
Review	9
Commentary	2

Table 6 Main topic discussed in the 100 most cited articles on lung cancer screening

Main topic	No. of articles
Screening strategy	12
Lung cancer risk factors	3
Screening study design	3
Screening test effectiveness	40
Nodule diagnosis	10
Mortality/survival	18
Smoking cessation	2
Automated detection	2
Screening risk	6
Cost-effectiveness	4

3,910 times. This milestone research from the National Lung Screening Trial (NLST) is the first trial to date that has shown that screening with LDCT reduces lung cancer mortality. The NLST provided confirmatory evidence to support lung cancer screening with LDCT instead of CXR. To date, three screening tests have been studied to determine whether they decrease the risk of dying from lung cancer, and LDCT is the only screening test shown to lower the chance of dying from lung cancer. The results from the NLST and other key studies resulted in the United States Preventative Services Task Force Grade B recommendation to use screening with LDCT for early detection of lung cancer and generated much excitement in the lung cancer community (30).

The bibliometric analysis on article type showed that these 100 most cited articles contained 79 original research articles (including 1 research letter), 10 guideline/consensus/statement, 9 reviews and 2 commentaries. Among the original research articles, there was a higher proportion of RCTs (37.9%) than in other similar bibliographic analyses (*Table 5*) (17,31,32). These articles covered 10 topics related to lung cancer screening, with screening test effectiveness being the most frequent topic. Lung cancer screening articles cover contains wide range of topics, including high-risk population selection, screening design and protocol, test modality and effectiveness, nodule diagnosis and management, and modality reduction, which require multidisciplinary cooperation and collaboration. Beyond the benefits of mortality reduction and smoking cessation, lung cancer screening can also generate potential harms such as false-positive results, overdiagnosis, radiation

risk, and added cost. The potential benefits and risks for each candidate need to be evaluated and balanced, especially by high-level evidenced studies such as RCTs. Moreover, LDCT provides a large number of images, which in the future need to be analyzed by a new computer-assisted system or artificial intelligence (33). These features of lung cancer screening may have resulted in the diverse distribution of article types and topics in our study.

Several limitations to our study should be considered. First, citation analysis maybe not a perfect measure of the impact an article has on its field. Articles published more recently are at a disadvantage because less time has elapsed from the date of publication to allow for citations. Therefore, a potential milestone article published in 2020 was not included in this research (34). However, the number of citations is currently still the best and simplest measurement for studies, and old articles can show the historical development in this field. Second, the impact of self-citations was also not considered. Self-citation has not been shown to have a major impact on bibliometric measures, especially over a long duration (35). Third, the h-index is a new author-level metric that attempts to measure both the productivity and citation impact of the publications and it is considered to be a more comprehensive quantitative measurement of a scholar (10,36,37). However, our study was focus on the article instead of author, so the h-index was not introduced in this study.

In conclusion, this study demonstrates the bibliometric and professional characteristics of lung cancer screening. The results may also provide an important framework to understanding the historical advancements and trends of lung cancer screening as well as the potential future research opportunities for researchers.

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Footnote

Data Sharing Statement: Available at http://dx.doi.org/10.21037/atm-20-3199

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/atm-20-3199). ML served as the unpaid Section Editor of *Annals of Translational Medicine* from Jan 2020 to Dec 2020. Dr. CIH is a named inventor on a number of patents and patent applications relating to the evaluation of pulmonary nodules on CT scans of the chest which are owned by Cornell Research Foundation (CRF). Since 2009, Dr. CIH does not accept any financial benefit from these patents including royalties and any other proceeds related to the patents or patent applications owned by CRF. Dr. CIH is the President and serve on the board of the Early Diagnosis and Treatment Research Foundation. I receive no compensation from the Foundation. The Foundation is established to provide grants for projects, conferences, and public databases for research on early diagnosis and treatment of diseases. Recipients include, I-ELCAP, among others. The funding comes from a variety of sources including philanthropic donations, grants and contracts with agencies (federal and non-federal), imaging and pharmaceutical companies relating to image processing assessments. The various sources of funding exclude any funding from tobacco companies or tobacco-related sources. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Ethics committee approval was exempted as this study was a retrospective bibliometric analysis of existing published classical studies.

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