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Original Scientific Paper

A QUARTER CENTURY OF CROATIAN RADIOLOGY PUBLICATIONS: A BIBLIOMETRIC ANALYSIS

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SUMMARY – The aim was to analyze Croatian radiology publications, the number of radiologists *per* 100,000 population from 1992 to 2016, as well as their citation metrics until 2018. MEDLINE database was searched through the Web of Science platform and estimated the annual number of radiologists *per* 100,000 population. Articles were categorized by subspecialty, citation count, journal impact factor (JIF), mean number of authors *per* article, study design, and journal type (radiology *vs*. non-radiology; foreign *vs*. domestic). Publication activity positively correlated with radiologists' rate and articles from neuroradiology/head and neck and vascular/interventional radiology predominated. There were 177 articles, 1,391 citations (7.85 *per* article), and 19 uncited *vs*. 157 cited articles (8.8 *per* article). The majority were published in non-radiology and foreign journals, however, the articles in foreign and radiology journals were more frequently cited. The mean number of authors *per* article remained stable, but the mean JIF increased significantly from 1.09 to 1.82. The dominant study designs were cross-sectional and case reports; JIF was similar across study designs. In conclusion, this study provides a comprehensive overview of bibliometric indicators in Croatian radiological publications and allows radiologists to critically re-evaluate their publication activity and direct their focus toward implementing them into research practice.

Keywords: *Croatia; Radiology; Bibliometric analysis; Radiology publications*

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Introduction

The field of radiology has evolved rapidly in recent decades. This development is visible in the widespread integration of digital imaging into clinical practice. Complex computer-based imaging technology has consequently generated a great amount of data; although this facilitates publication, it does not necessarily guarantee that research is of high quality. The extent and quality of medical research may be assessed nationwide for a particular country of interest by measuring the number of publications originating from the said country over time. Bibliometrics is the scientific analysis of written publications within the scientific and applied fields. Although several studies about Croatian scientific production have already been published, none of them has focused specifically on the field of radiology[1-3].

The aim of this study was to analyze Croatian radiological publications according to bibliometric indicators, and the number of radiologists *per* 100,000 population from 1992 to 2016, and citation metrics until the end of 2018.

Material and Methods

The number of radiologists was obtained from the Health Workers Registry of the Croatian Institute of Public Health. The annual numbers of radiologists *per* 100,000 population were estimated according to the 1991, 2001, and 2011 population censuses[4].

MEDLINE database search strategy

Bibliometric analysis was conducted using the MEDLINE database through Clarivate Analytics Web of Science (WoS) platform in November 2017. The search was performed using the root term radiology (radiol*) and Croatia in the address field. As Croatia gained independence in 1992, we included articles from January 1, 1992 to December 31, 2016 using the search strategy: (AD=(radiol* SAME croatia)) AND LANGUAGE:(English) Indexes=MEDLINE Timespan=1992-2016.

MEDLINE articles include the location of the first author's department; this field was used to determine author affiliations. Our search consisted of assigning the origin of each article to the country of the first author as described in a previous study[5]. Until 2014, the affiliation field included only first author affiliations. As this first-author method did not take the contributions of other authors into account, multiple affiliations for each author were included after December 2014. For this study, articles from 2014 to 2016 were manually selected for the appropriateness of their inclusion criteria across the entire period analyzed (1992-2016). Articles affiliated to departments of veterinary medicine were excluded.

Article characteristics

Articles were classified by JIF, citation count, subspecialty, mean number of authors *per* article, and study design.

Journal impact factor (JIF) was obtained through InCites Journal Citation Reports. Articles with JIF were categorized into >0.0-1.0, >1.0-2.0, >2.0-3.0, >3.0-4.0, >4.0-5.0, and >5.0-6.0 intervals. Furthermore, journals were classified into foreign *vs*. domestic (Croatian) and radiology *vs*. non-radiology. The leading journals were ranked according to their number of published articles.

A search of the Web of Science All databases in January 2019 resulted in citation counts as of December 31, 2018 and the mean number of counts *per* article. The proportion of articles and citation counts were analyzed according to subspecialties: abdominal, breast, cardiac, chest, genitourinary, musculoskeletal, neuroradiology/head and neck, pediatric, vascular/interventional, and miscellaneous (not falling within one of the aforementioned categories, including whole body imaging, nuclear medicine, physics, basic science, radiation oncology, contrast media, radiation protection).

Two epidemiologists and a radiologist classified the study design of the articles by MEDLINE tagging as case reports, case series, cross-sectional, case-control, cohort, non-randomized control trial (NRCT), randomized control trial (RCT), and review; number of authors *per* article was also recorded. In case of disagreement, joint reading was performed and a consensus was reached. Letters to the editor and comments were excluded from the analysis.

This study did not involve human subjects and did not require institutional review board approval.

Statistical analysis

The results were presented numerically and graphically. For the analysis, the time period was divided into the following intervals: 1992-1996, 1997-2001, 2002-2006, 2007-2011, and 2012-2016. The number of radiologists *per* 100,000 general population and publication counts were presented annually. Time trend and annual percentage change (APC) were estimated. The number of radiologists *per* 100,000 general population was correlated with the number of publications using the Pearson test. Journals without JIF were excluded from the calculation of the mean JIF. The Kruskal-Wallis test was used to compare JIF and the mean number of authors across publication periods. The level of statistical significance was $p<0.05$. Analyses were performed using the IBM SPSS Statistics statistical package version 23, license held by the Croatian Institute of Public Health.

Results

The number of radiologists *per* 100,000 increased from 6.29 in 1992 to 10.87 in 2016, with an APC of 2.28%. This correlated moderately with the number of publications (r=0.73) (Fig. 1).

A total of 177 articles were published with an annual rate of 7.08 across 81 journals (76 foreign and 5 Croatian; 56 non-radiology journals and 25 radiology journals). The majority of articles (n=118) were published in non-radiology journals; 59 were published in radiology journals.

Croatian radiologists published more in foreign journals than in domestic journals, 71.2% (n=126) *vs.* 28.8% (n=51). A list of the journals with the highest number of published articles is presented in Table 1.

The majority of articles in domestic journals (49/51) were published in Collegium Antropologicum, Croatian Medical Journal, and Acta clinica Croatica, all of which are accessible in gold Open Access.

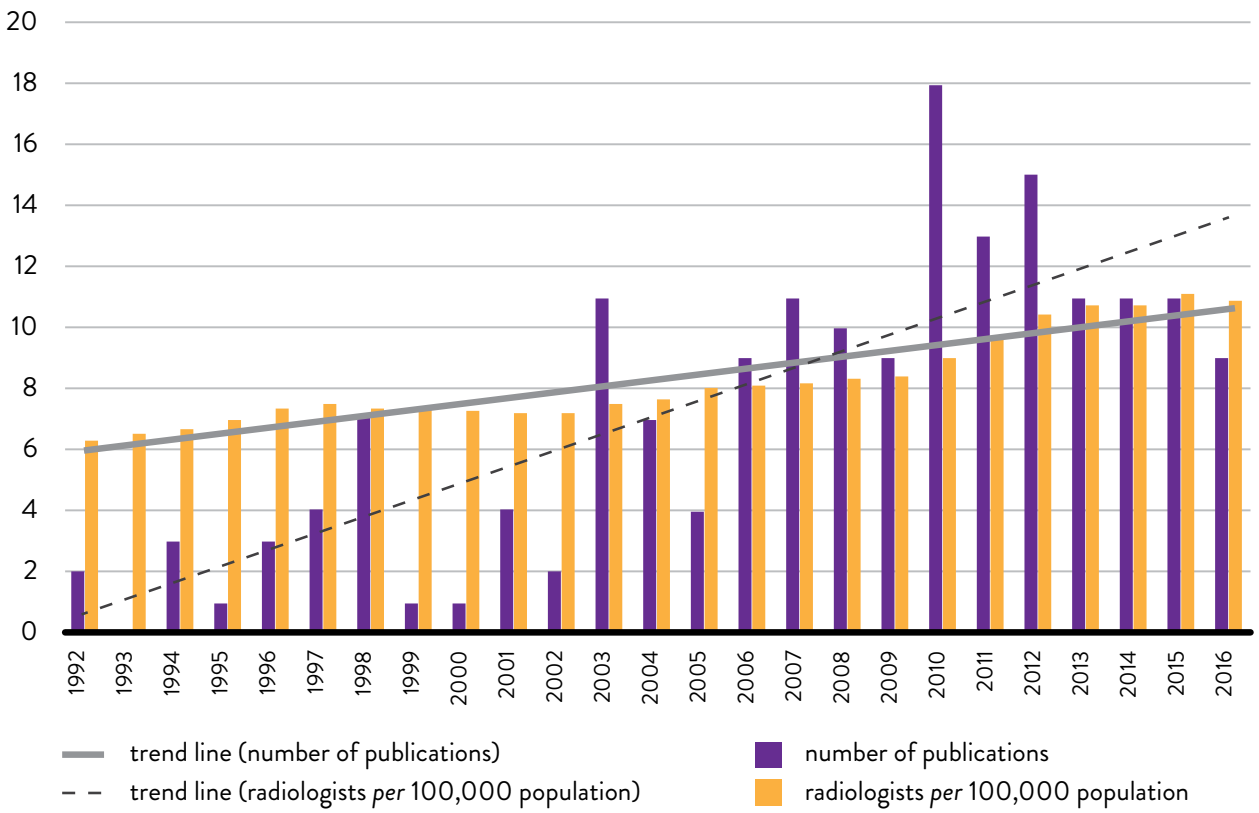

Fig. 1. Annual number of radiologists and publications.

Table 1. Leading journals according to the number of published articles

Journal	Articles (n)
Collegium Antropologicum	34
European Radiology*	11
Croatian Medical Journal	10
Acta clinica Croatica	5
European Journal of Radiology*	5
Journal of Clinical Ultrasound*	5
Military Medicine	5
Wiener klinische Wochenschrift	5
Clinical Imaging*	4
Radiology and Oncology*	4

*radiology journal; n = number

Articles received 1,391 citations with a mean of 7.85 *per* article. Nineteen articles remained uncited, while 157 cited articles had a mean of 8.8 citations. Total citations *per* article ranged from 1 to 71 with the annual rate ranging from 0.06 to 4.27. The most frequently cited article (71 citations) was published in 1998; it was cited for a mean of 3.23 times *per* year. Articles published in 2007 (n=11) received the highest number of citations (n=138). Articles in foreign journals were cited more frequently than those in domestic journals (1,145 *vs*. 236); these articles also had a higher mean citation count *per* article as compared to those published in domestic journals (9.08 *vs*. 4.82). The citation count in radiological *vs*. non-radiological journals was 614 *vs*. 777, with a mean of 10.40 *per* article as compared to 6.58, respectively.

Neuroradiology/head and neck and vascular/interventional subspecialties had the largest proportion of published articles (25.42% and 21.47%, respectively) and the highest citation count (Table 2).

The most frequent number of article authors was six (24.9%), followed by five (19.8%) and three (13.6%) (Fig. 2).

The mean number of authors *per* article (n=177) was 5.28 (SD=2.13). The mean JIF of articles published in journals with JIF (n=157) was 1.29 (SD=1.04). The correlation between the number of authors and JIF was not significant (p=0.47).

The mean JIF significantly increased over time from 1.09 to 1.82 (p<0.001), as opposed to the number of authors, which decreased from 5.30 to 5.00 (p=0.53) (Fig. 3).

More than two thirds (70.05%) of articles were published in journals with JIF<2 (Fig. 4).

The most frequent study designs were cross-sectional (39.50%) and case reports (28.80%) (Fig. 5). Differences in the mean JIF across study designs were not significant (p=0.49).

Table 2. Bibliometric indicators according to subspecialties

Subspecialty	Articles, n (%)	Citation (n)	Mean citations *per* article
Genitourinary	12 (6.78)	140	11.66
Neuro/head and neck	45 (25.42	486	10.80
Vascular/interventional	38 (21.47)	335	8.81
Cardiac	3 (1.69)	23	7.66
Chest	9 (5.08)	63	7.00
Abdominal	14 (7.91)	84	6.00
Musculoskeletal	22 (12.43)	114	5.18
Miscellaneous	23 (12.99)	108	4.69
Breast	8 (4.53)	30	3.75
Pediatric	3 (1.69)	8	2.66

n = number

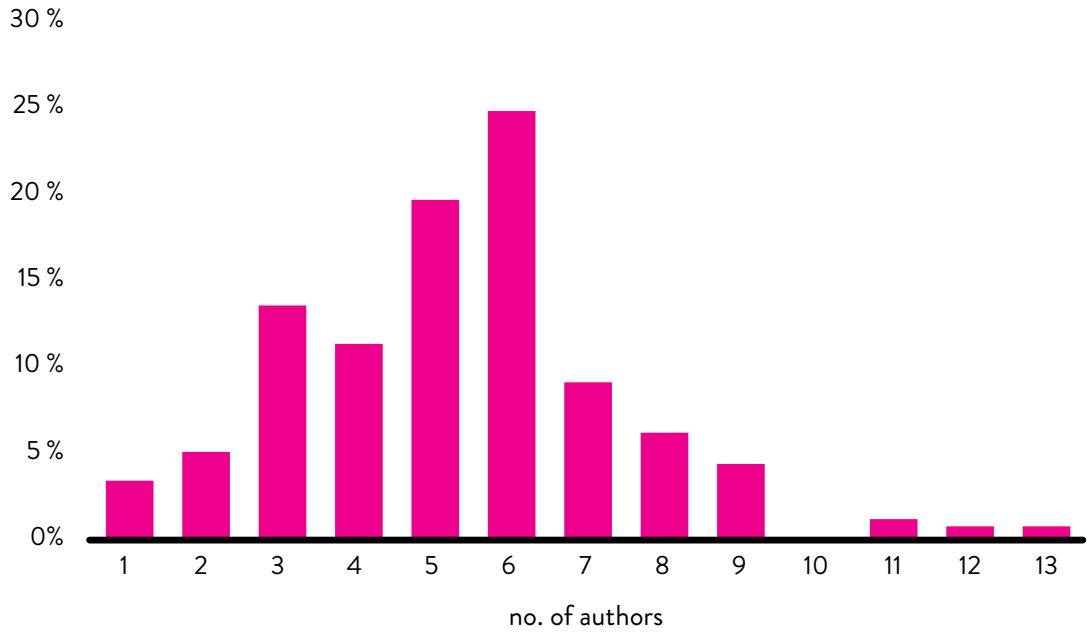

Fig. 2. Number of authors per article (%).

Fig. 3. Distribution of mean JIF and mean number of authors.

JIF – journal impact factor

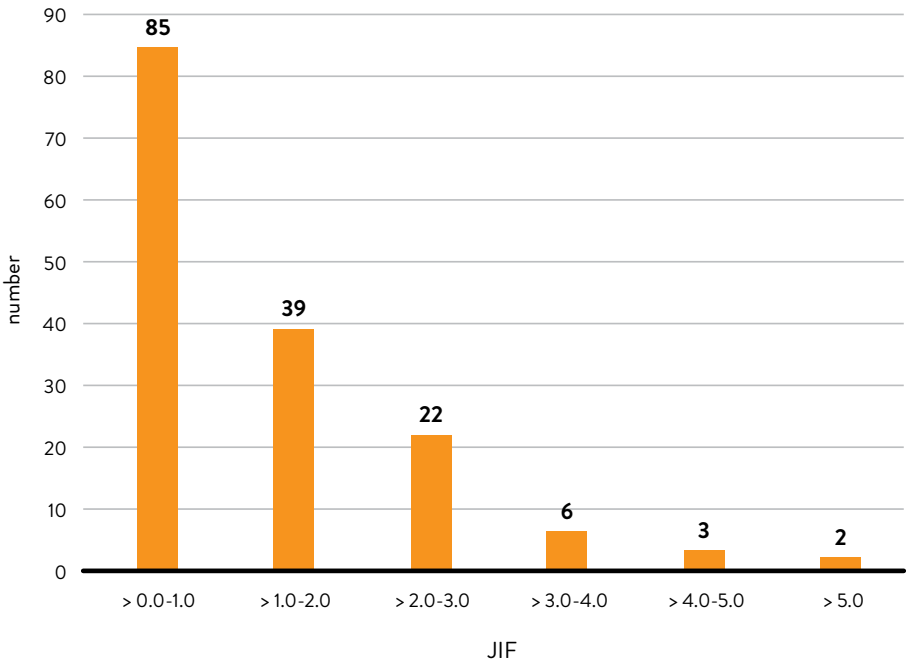

Fig. 4. Distribution of the journal impact factor.

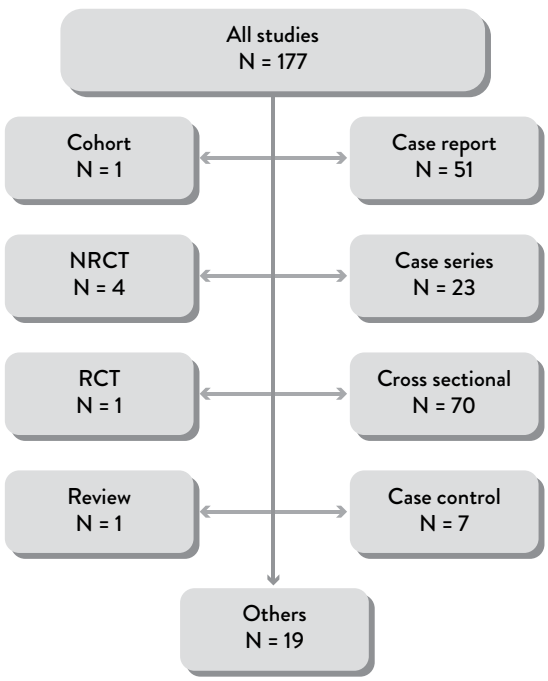

Fig. 5. Classification according to study design.

N = number of studies; RCT = randomized controlled trial; NRCT = non-randomized controlled trial

Discussion

This study presents the first bibliometric analysis of Croatian radiological publications, taking into account a period of twenty-five years. Positive correlation was found between the number of articles and number of radiologists *per* 100,000 general population. A similar trend was observed worldwide, with only a modest contribution (0.095%) from Croatian radiologists (data not shown)[6]. There are pronounced differences in the number of radiologists *per* 100,000 general population in European countries, ranging from 7.5 in the United Kingdom to 31 in Greece[7]. Although the Croatian radiological workforce increased by 76% from 6.2 to 10.9 *per* 100,000 general population, the numbers remain below the European Union mean of 12.7 (Fig. 1 and 2). A positive trend in publication seems to be facilitated by both the development of imaging techniques and the availability of modern radiological equipment in everyday patient care.

Modern medical imaging has become indispensable not only for diagnosing, but also for treating and following up various diseases. Clinical demands have facilitated the use of computed tomography and

magnetic resonance scanners, replacing the stereotype of radiologists as 'back-room doctors' and placing them in the forefront of patient care.

In general, the rapid transformation of radiology over the past several decades has increased its visibility and yielded numerous subspecialties. Imaging techniques have particularly progressed in neuroradiology[8]. In this study, articles in neuroradiology/head and neck and vascular/interventional contributed most to publishing output (25.42% and 21.47%, respectively). The reasons for this result are quite complex. The creation of interventional radiological laboratories in major health and university centers likely facilitated this publication activity. The academic setting of university centers certainly provides more support for publication activity. Nevertheless, the proportion of publications is only one measure of research productivity and it is considered less valuable than citation counts. Citation counts measure impact and influence; according to this indicator, genitourinary articles are most influential. With a proportion of 6.78%, genitourinary articles have the highest mean citation count *per* article, as well as the most cited article (n=71). At just 1.7%, cardiac articles can also be considered influential (Table 2). Regarding journal type, Croatian radiologists prefer to publish in non-radiology journals, which could be associated with the disproportionally high number of case reports in journals dedicated to different medical fields and not necessarily confined to imaging. However, articles published in foreign and radiology journals received more citations. The nineteen uncited articles had a less complex study design (case reports, n=9) and were published in non-radiology (n=12) and foreign (n=13) journals; they were less likely to be cited in the 2012-2016 period (n=11).

Bibliometric analysis indicates quantity, quality, and connections between publications, authors, or research fields[9]. Quality measurement remains the most controversial aspect, with numerous limitations. To assess quality, mean JIF was used as the most common criterion. Aware of its complexities, its creator Garfield called it 'mixed blessing', and stated that it should be used rationally[10,11]. Nowadays, scientific evaluation requires multidimensional assessment and the use of new metrics, such as altmetrics. Still, debate on the use and misuse of JIF continues and is unlikely to end in the near future[12-14]. Despite inappropriate interpretations, increases in JIF may still serve as a confidence booster and marketing tool even to renowned journals such as the British Journal of Radiology[15]. In the current study, JIF increased significantly over time, although the vast majority of articles (78.98%) were still published in journals with JIF <2.0 (Fig. 4). The widespread perception is that JIF represents the quality of an academic journal taking a specific field into account; e.g., the top ranked radiology journal in 2016, JACC-Cardiovascular Imaging, had a JIF of 10.19. JIF distribution in our study could be explained through the lower financial and technical resources of the authors' institutions, limited time dedicated to research, and the non-English speaking background of authors, given that English-language journals demand a high standard of fluency in scientific writing[16].

Our results did not confirm a positive association between JIF and authorship frequency (i.e., count of authors *per* article). The decrease in authorship frequency from 5.3 to 5.0 could be ascribed to the use of smaller research groups, or possibly to the absence of single and multi-center cooperation[17]. Authorship frequency has a multifactorial nature and could be associated with research complexity, academic advancement, and departmental funding. Compared with other medical specialties, radiology is in an unfavorable position in terms of funding in Croatia and some other countries[18]. Although an increase in the number of authors was not observed in our study, this has been shown to represent a serious issue in the scientific community, with great variations among journals and countries[6,19-21]. The well-known phenomenon of honorary authorship contributed to this positive trend, with a surprisingly high proportion of 26.0%[22].

The study design may indirectly indicate publication quality. However, the results of this study did not associate more complex study design with higher JIF. Given that the vast majority of Croatian radiologists work in a non-scientific setting, they prefer more feasible study designs, such as cross-sectional studies (39.50%) or the smallest publishable units, i.e., case reports (28.80%) and case series (13.00%). Some hospitals issue financial rewards *per* published paper, which may facilitate the production of less complex studies with a lower number of authors. High clinical workload may negatively influence research

productivity, as described previously[23,24]. Other possible causes for the production of methodologically less complex studies could be the lack of structured institutional support, insufficient education in research methodology, or low research mobility, especially in national and international collaboration. Nonetheless, recently in some academic hospitals in Croatia collaborative multidisciplinary research and methodology knowledge exchange between radiologists and other specialties has been established and resulted in qualitative scientific output[25-27]. Such practice may facilitate more complex study designs that are prospective in nature and furthermore increase the visibility of published articles.

This study had some limitations. We focused on MEDLINE database entries, while other databases may have yielded slightly different results. MEDLINE database was selected since relatively long time period in our analysis included era when other scientific databases such as WoS and Scopus were not available. Furthermore, during most of the analyzed period, MEDLINE publications were the criterion for academic promotion and therefore appropriate choice for bibliometric analysis. For the same reason and aware that nowadays the majority of databases provide quartile rankings, we could not use such distribution since it was not available for the entire period. Still, it remains as a possibility for follow-up analyses. Nonetheless, extensiveness and easy usability of Clarivate Analytics' Web of Science (WoS) platform enabled most accurate data sampling. Articles were retrieved on the basis of how the authors listed themselves, which may have led to the omission of data by the authors, i.e., the under-recognition of authors' institutions/departments. Authors sometimes omitted the terms "radiology" (and its derivatives) and "Croatia". In the majority of cases, they used "Department of Radiology", and not "radiology department" as defined by their institutions. Not all institutes, departments, and clinics listed themselves consistently with the same name; the way authors choose list themselves cannot be influenced. This may have resulted in some papers not being encompassed by the study.

Conclusion

This is the first bibliometric assessment of Croatian radiology publications. It illustrated an increase in the number of articles and mean JIF, while authorship frequency remained unchanged. Articles published in radiology and foreign journals were more influential, however, radiologists published more articles in non-radiology journals. More than 2/3 of the articles were published in journals with JIF <2.0 This study provides the first deep insight into radiological research indicators in Croatia. The results of this study will allow radiologists to critically re-evaluate their scientific and publication activity. Furthermore, these results can serve as the foundation for more detailed bibliometric analyses.

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Sažetak

ČETVRT STOLJEĆA HRVATSKIH RADIOLOŠKIH PUBLIKACIJA: BIBLIOMETRIJSKA ANALIZA

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Cilj je bio analizirati hrvatske radiološke publikacije, broj radiologa na 100.000 stanovnika od 1992. do 2016. godine, kao i njihove metrike citiranja do 2018. godine. Baza podataka MEDLINE pretražena je putem platforme *Web of Science* i procijenjen je godišnji broj radiologa na 100.000 stanovnika. Članci su kategorizirani prema supspecijalnosti, broju citata, čimbeniku utjecaja časopisa, prosječnom broju autora po članku, dizajnu studije i vrsti časopisa (radiologija naspram neradiologije; strani naspram domaćih). Publikacijska aktivnost pozitivno je korelirala sa stopom radiologa, a prevladavali su članci iz neuroradiologije/glave i vrata te vaskularne/interventne radiologije. Bilo je 177 članaka, 1391 citata (7,85 po članku) i 19 necitiranih naspram 157 citiranih članaka (8,8 po članku). Većina je objavljena u neradiološkim i stranim časopisima, međutim, članci u stranim i radiološkim časopisima bili su češće citirani. Prosječan broj autora po članku ostao je stabilan, ali prosječni čimbenik utjecaja časopisa značajno se povećao s 1,09 na 1,82. Pretežiti dizajni studija bili su presječni i prikazi slučajeva; čimbenik utjecaja je bio sličan u svim dizajnima studija. Zaključno, ova studija pruža sveobuhvatan pregled bibliometrijskih pokazatelja u hrvatskim radiološkim publikacijama i omogućuje radiolozima da kritički preispitaju svoju publikacijsku aktivnost i usmjere svoj fokus prema njihovoj primjeni u istraživačku praksu.

Ključne riječi: *Hrvatska; Radiologija; Bibliometrijska analiza; Radiološke publikacije*