



# Current Problems in Diagnostic Radiology

journal homepage: [www.cpdjournal.com](http://www.cpdjournal.com)



## Trends in Interventional Radiology Through the Eye of the Journal of Vascular and Interventional Radiology: A 27-Year History

Jacob J. Bundy, MD, MPH<sup>a</sup>, Anthony N. Hage, MD<sup>b</sup>,  
 Jeffrey Forris Beecham Chick, MD, MPH, DABR<sup>b</sup>, Joseph J. Gemmete, MD, FSIR<sup>b</sup>,  
 Rajiv N. Srinivasa, MD<sup>b</sup>, Eunjee Lee, Ph.D<sup>c</sup>, Evan Johnson, MD<sup>b</sup>, Jawad Hussain, MD<sup>b</sup>,  
 Michael Cline, MD<sup>b</sup>, Nishant Patel, MD, MBA<sup>b</sup>, Ravi N. Srinivasa, MD<sup>b,\*</sup>

<sup>a</sup> College of Human Medicine, Michigan State University, Grand Rapids, MI

<sup>b</sup> Department of Radiology, Division of Vascular and Interventional Radiology, University of Michigan Health System, Ann Arbor, MI

<sup>c</sup> Department of Biostatistics, School of Public Health, University of Michigan, Ann Arbor, MI

### ABSTRACT

**Purpose:** To report the quantity, manuscript types, geographic distribution of publications, and published content trends in a major interventional radiology journal over 27 years.

**Materials and Methods:** Available publication data from the *Journal of Vascular and Interventional Radiology* was collected via Scopus from November 1990 to November 2017. Quantity, manuscript type, geographic distribution, number of citations, and publication content were analyzed.

**Results:** 6925 papers were published in *JVIR* during the study period. The number of publications increased by 234% from an average of 103 publications/year in the first 5 years to 344 publications/year in the last 5 years. Manuscript types included 4891 original articles (70.6%), 987 letters (14.3%), 360 review articles (5.2%), 324 notes (4.7%), 167 conference papers (2.4%), 102 editorials (1.5%), 61 errata (0.9%), 23 articles in press (0.3%), and 10 short surveys (0.1%). The majority of publications originated in the United States with 3945 articles (57.0%), followed by Canada with 366 articles (5.3%), and Japan and South Korea with 360 (5.2%) and 340 articles (4.9%), respectively. As for article content, arterial disease and interventions were discussed in 2256 publications (32.6%), followed by venous (1237; 17.9%), miscellaneous (1072; 15.5%), oncology (1006; 14.5%), genitourinary (758; 10.9%), portal (337; 4.9%), neurovascular (253; 3.7%), gastrointestinal (232; 3.4%), biliary (210; 3.0%), pediatric (130; 1.9%), clinical trials (119; 1.7%), and guideline development (119; 1.7%).

**Conclusion:** There has been a marked increase in the number of publications in *JVIR* over 27 years. *JVIR* has shown continued growth since its inception and has strengthened its international reputation with more global research than ever before.

© 2018 Elsevier Inc. All rights reserved.

### Introduction

Interventional radiology has grown tremendously since the development of the Seldinger technique in 1953 and the introduction of selective angiography in the early 1960s.<sup>1–3</sup> With the expansion of the field has also come an increasing emphasis on innovation and research. The *Journal of Vascular and Interventional Radiology (JVIR)* released its first publication in November 1990 and now serves as the official journal for the Society of Interventional Radiology.<sup>4</sup> Since its inception, *JVIR* has served as the global forum for scientific inquiry in the field of vascular and interventional radiology. However, when tracing the history of a field as dynamic as interventional radiology, the patterns of creativity and innovation are not always readily apparent. The development of bibliometric platforms has permitted investigators to evaluate scientific publications using mathematical and statistical models.<sup>5,6</sup> The

information gathered through the use of bibliometrics facilitates the characterization of academic trends within a specific field.

The goal of this investigation is to assess the trends in interventional radiology, with particular focus on the internationalization of research foci and the shifts in interventional radiology research content through the perspective of *JVIR* over 27 years.<sup>7</sup>

### Materials and Methods

#### Data Collection

This study was conducted with institutional review board approval and complied with the Health Insurance Portability and Accountability Act. Informed consent was not required for this study. A retrospective search of the Scopus (Elsevier; Amsterdam, Netherlands) database for the *JVIR* was performed from November 1990 to November 2017 (27 years). The Scopus dataset included publication date, document title, and author and issue information. Articles were also classified by type (eg, original study, clinical study, review article, or letter to the editor), geographic distribution, and content.

\* Reprint requests: Ravi N. Srinivasa, MD, Department of Radiology, Division of Vascular and Interventional Radiology, University of Michigan Health System, 1500 East Medical Center Drive, Ann Arbor, MI 48109.

E-mail address: [jeffreychick@gmail.com](mailto:jeffreychick@gmail.com) (J.F.B. Chick), [medravi@gmail.com](mailto:medravi@gmail.com) (R.N. Srinivasa).



FIG 1. Number of annual JVIR publications from 1990 to 2017.

Variables

Quantity, manuscript type (ie, original study, clinical study, review article, or letter to the editor), geographic distribution (institution and location), content, and number of citations were quantified. Manuscript content was determined by keyword search, and content categories include oncology, biliary, arterial, venous, portal, gastrointestinal, genitourinary, neurovascular, and pediatric interventions. Quality improvement, clinical trials, and miscellaneous interventions were also categorized. For a complete list of the keywords used see Supplementary Table 1. The keyword search identified 5164 articles (74.6%). Each article was not limited to 1 category.

Heat Maps

Heat maps were generated using myHeatmap (Charlotte, NC), a commercially available heat map generator. Location was determined by coordinates of the institution affiliated with the publication (Fig 3).

Statistical Analyses

All data were tabulated and used to calculate percentages using on-board analytics of the Scopus platform (Elsevier) as well as spreadsheet software (Excel 2017; Microsoft; Redmond, WA). A negative binomial autoregressive regression model was used to assess content categories for statistically significant changes over the study period using the R statistical program (Vienna, Austria).

Results

Total Publications

Throughout the 27-year study period, there were a total of 6925 articles published in JVIR (Fig 1). The average number of publications per year was 256 (range: 27–370), with an average of 103 publications/year over the first 5 years of the study period, and an average of 344 publications/year over the last 5 years. This change represents a 234% increase in the total number of publications between the 2 time periods.

Manuscript Types

Manuscript types totaled 4891 original articles (70.6%), 987 letters (14.3%), 360 review articles (5.2%), 324 notes (4.7%), 167 conference papers (2.4%), 102 editorials (1.5%), 61 errata (0.9%), 23 articles in press (0.3%), and 10 short surveys (0.1%) over the course of the study period (Fig 2).

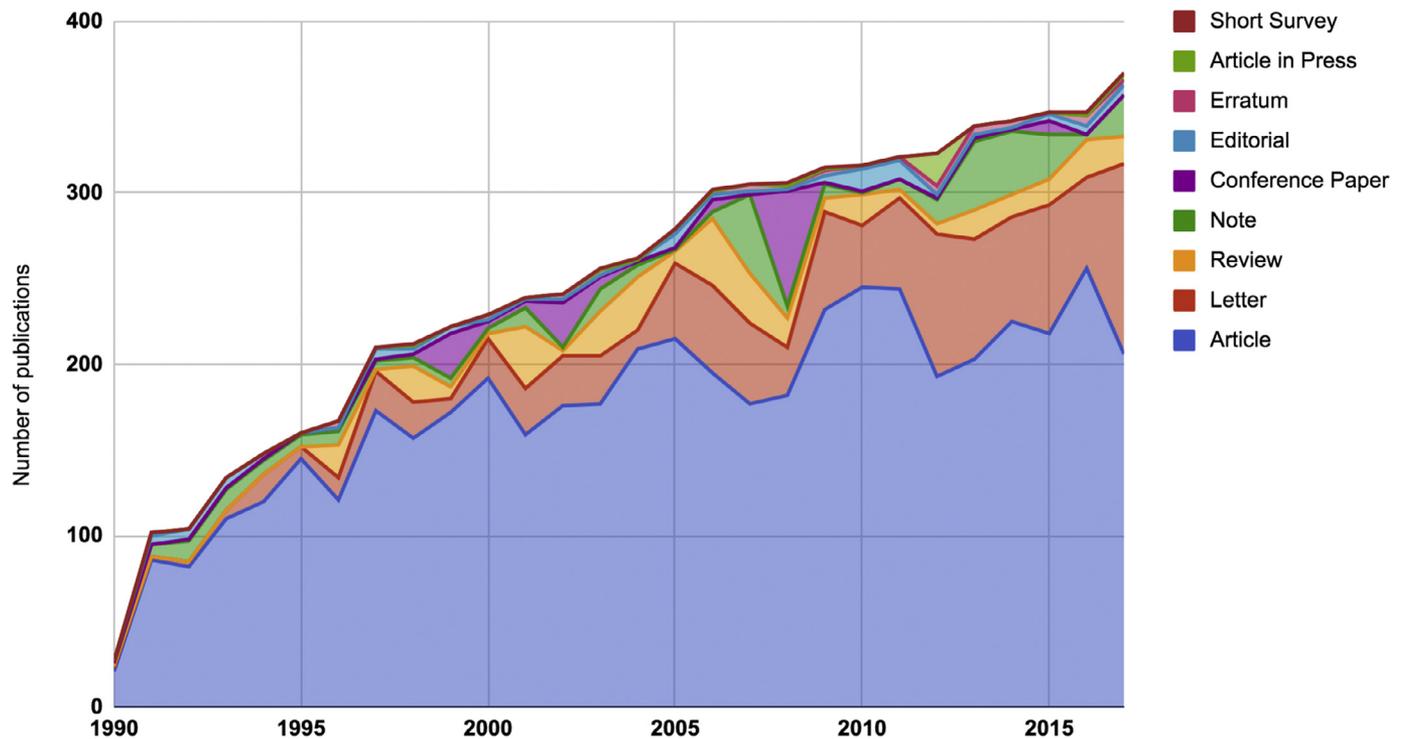


FIG 2. Annual JVIR publication type distribution from 1990 to 2017.

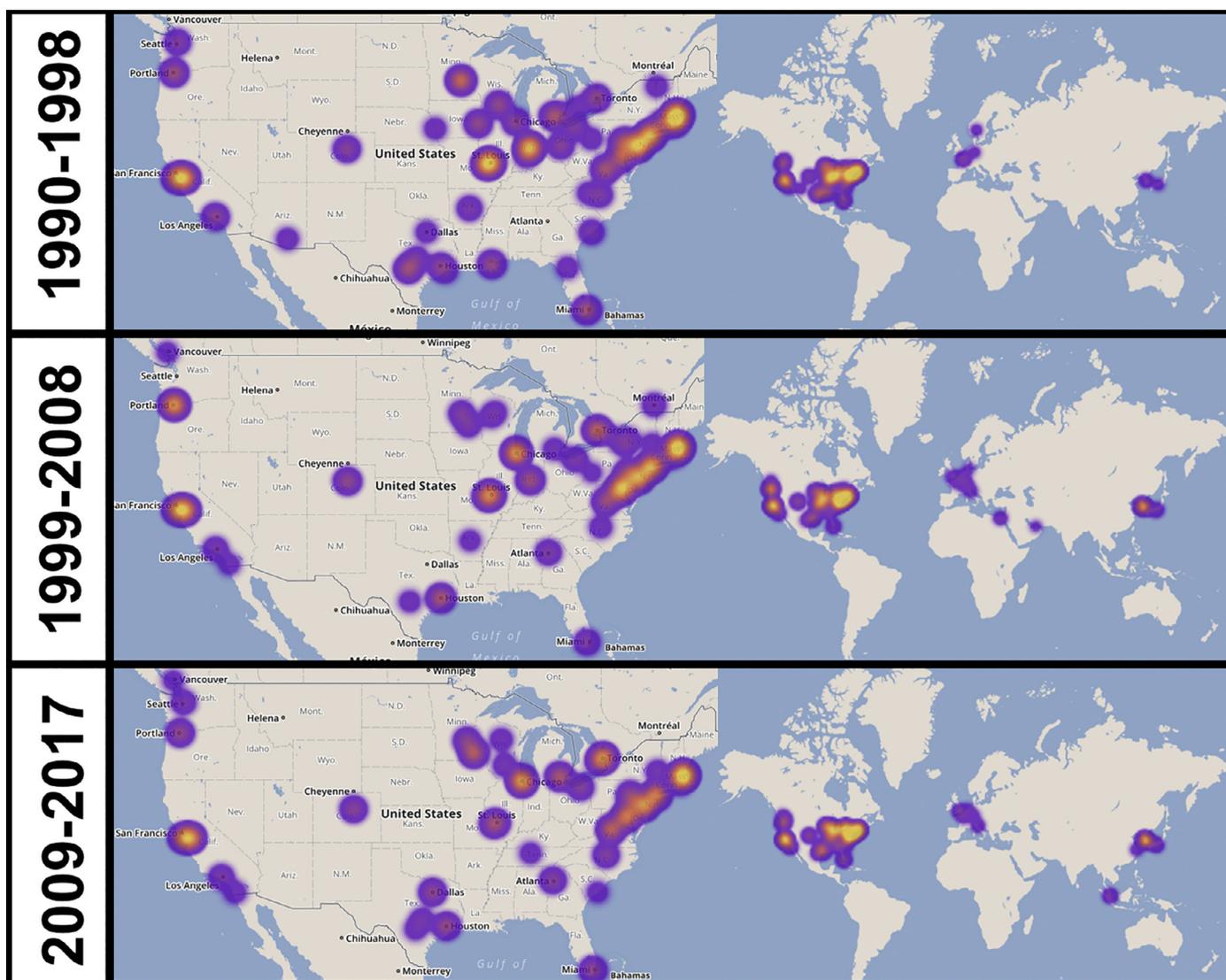


FIG 3. Geographic heat maps of the top 100 institutions by *JVIR* publication output over the indicated time periods.

### Geographic Distribution

Figure 3 depicts 3 geographic heat maps displaying top 100 institutions by *JVIR* publication output over the indicated time periods. The majority of publications originated in the United States (3945; 56.7%) followed by Canada (366; 5.3%), Japan (360; 5.2%), and South Korea (340; 4.9%). With respect to individual institutions, the University of Pennsylvania produced the most publications over the lifetime of the journal (220; 3.2%), followed by Massachusetts General Hospital (175; 2.5%), Harvard Medical School (165; 2.4%), and Edward Mallinckrodt Institute of Radiology (141; 2.0%).

### Content Trends

Publications regarding arterial disease and interventions were most frequently published over the study period accounting for 2256 publications (32.6%), followed by venous (1237; 17.9%), miscellaneous (1072; 15.5%), oncology (1006; 14.5%), genitourinary (758; 10.9%), portal (337; 4.9%), neurovascular (253; 3.7%), gastrointestinal (232; 3.4%), biliary (210; 3.0%), pediatric (130; 1.9%), clinical trials (119; 1.7%), and guideline development (119; 1.7%; Fig 4). All content categories had significantly positive content trends except for biliary and quality improvement guidelines after Bonferroni corrections at

the 0.05 significance level (Table 1). Figure 5 depicts the content categories over time as they relate to the annual number of citations.

### Discussion

Since the introduction of *JVIR* in 1990, the annual publication rate has grown significantly, with an increasing representation of authors internationally. This trend appears to reflect the increasing number of interventional radiology trainees, and the expanding treatment modalities offered by interventional radiologists.<sup>8-10</sup>

Articles have remained the predominant form of publication over time in *JVIR*. Interestingly, letters gained a remarkable share of published manuscripts growing from an average of 5% during the first 5 years to 21% during the last 5 years. This trend may reflect an increase in the willingness to attempt novel solutions during difficult clinical scenarios and the desire to disseminate these approaches to fellow interventional radiologists. Additionally, the types of novel interventions proposed by many authors may only be applicable in a small subset of patients, thereby limiting the ability to collect statistically significant results.

As for *JVIR* publication content trends, there has been a significant increase in the output of publications related to oncology. This correlates with the development and widespread adoption of transcatheter chemoembolization, Yttrium-90 radioembolization, and the

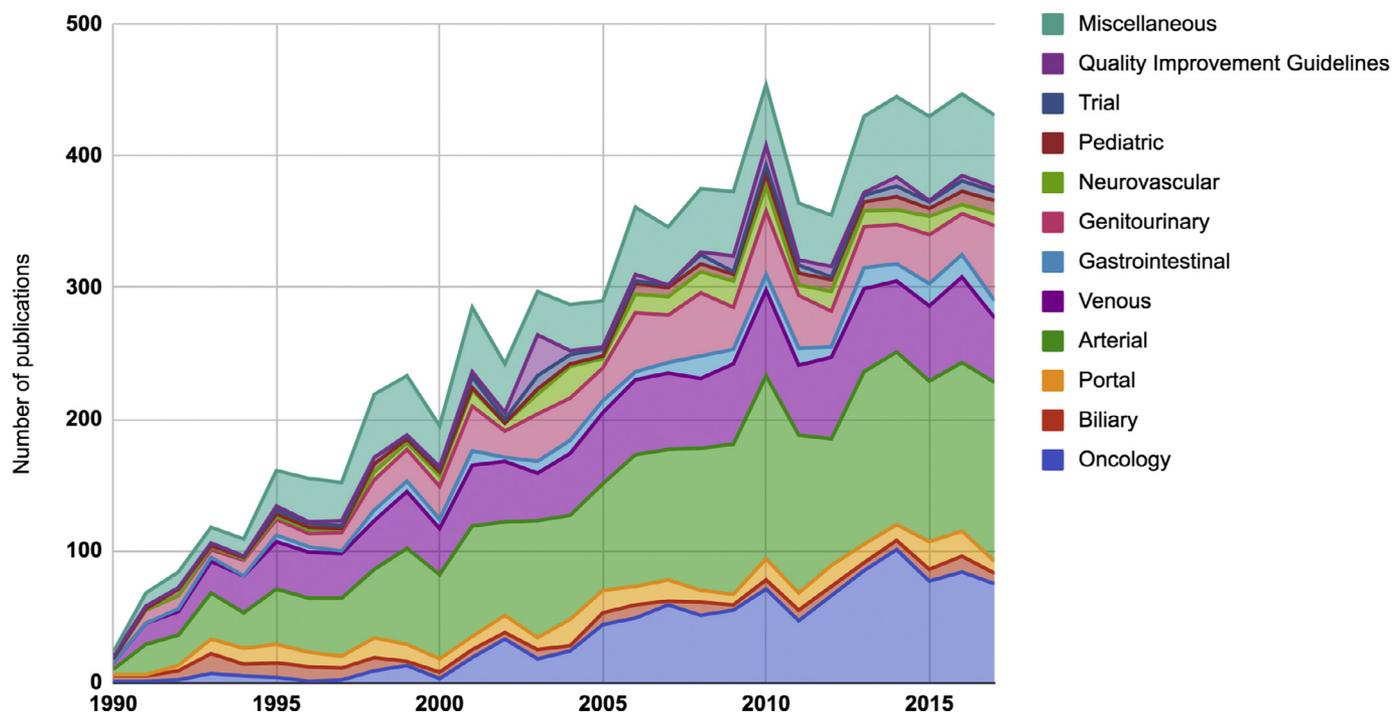


FIG 4. Annual JVIR publication subject matter distribution from 1990 to 2017.

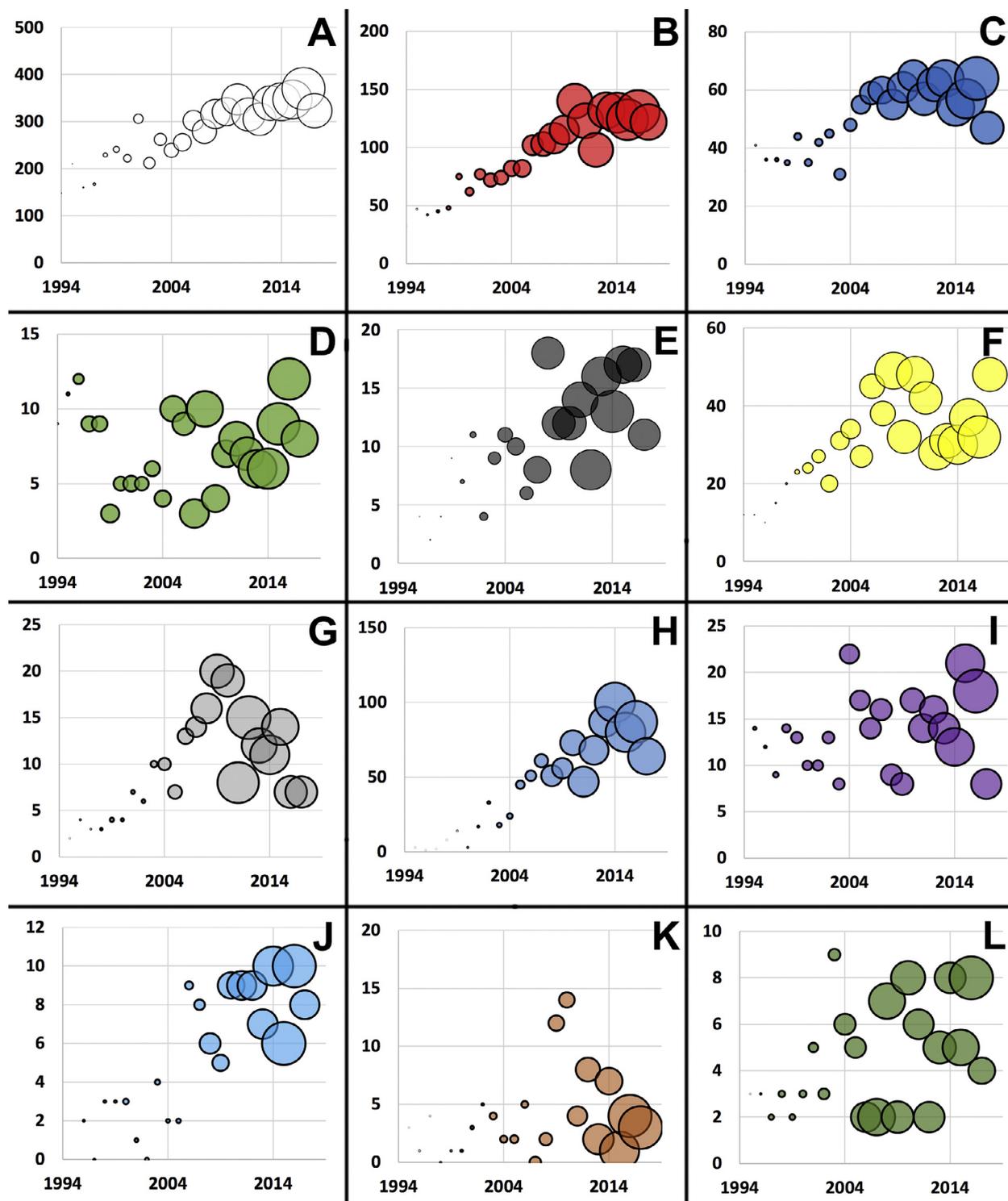
TABLE 1  
Interventional radiology content categories published in JVIR between 1990 and 2017

Year	Oncology	Biliary	Portal	Arterial	Venous	Gastrointestinal	Genitourinary	Neurovascular	Pediatric	Trial	Quality improvement guidelines	Misc.
1990	1	4	1	4	5	0	3	0	0	1	1	3
1991	1	4	1	23	16	0	10	0	1	2	0	10
1992	2	7	4	23	18	2	10	0	5	1	0	12
1993	7	15	11	35	24	3	6	2	1	2	0	12
1994	5	9	12	27	28	0	12	1	1	1	0	13
1995	4	11	14	42	36	5	12	2	2	3	3	27
1996	1	11	11	41	35	4	10	3	2	3	1	33
1997	2	9	9	44	34	2	14	3	0	2	4	29
1998	9	10	15	52	37	8	23	6	6	5	0	48
1999	13	3	13	73	43	8	24	5	3	2	1	45
2000	3	5	10	64	35	7	25	8	3	3	1	31
2001	19	6	10	84	46	11	34	12	2	8	4	49
2002	33	5	13	71	46	3	20	6	0	3	5	37
2003	18	7	9	89	36	9	36	15	4	10	31	33
2004	24	4	20	79	47	10	32	24	2	7	3	35
2005	44	9	17	81	54	9	25	7	2	5	2	35
2006	49	10	14	100	57	6	45	14	8	2	5	51
2007	59	3	16	99	58	8	36	14	7	2	0	44
2008	51	10	9	108	53	17	48	16	6	7	2	48
2009	55	4	8	114	61	11	32	20	5	2	12	49
2010	71	7	16	139	65	12	48	19	9	7	15	46
2011	47	8	13	120	53	13	40	8	9	6	4	43
2012	66	7	16	96	62	8	27	15	9	2	8	39
2013	85	6	14	131	63	16	31	12	7	5	2	58
2014	101	7	12	131	54	13	30	11	10	8	7	61
2015	77	9	21	122	57	17	37	14	6	5	1	64
2016	84	12	19	128	65	17	31	7	10	8	4	62
2017	75	8	9	136	49	13	57	9	10	7	3	55
Pvalue	< 0.0001*	0.994	0.0037*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	0.0021*	< 0.0001*	0.0003*	0.0259	0.0038*

\*Statistically significant at <0.004 after Bonferroni corrections at the 0.05 significance level.

various ablative techniques for the treatment of hepatocellular carcinoma and other solid organ malignancies.<sup>11-16</sup> As our understanding of the applications and efficacy of interventional oncologic treatments continues to expand, we should expect the research trends in JVIR to continue to reflect this intellectual growth. Additionally, there has been a consistent increase in the number of publications related to

peripheral vascular interventions since 1990. The fact that arterial and venous publications accounted for 43% of all JVIR publications over the last 5 years supports that interventional radiologists are still invested and innovating in the realm of peripheral vascular interventions. However, it should be noted that the increase peripheral vascular publications in large part related to an increase in venous disease



**FIG 5.** Number of *JVIR* publications from 1994 to 2017 with bubble diameter proportional to the number of annual citations within each given category. (A) All publications, (B) arterial, (C) venous, (D) biliary, (E) gastrointestinal, (F) genitourinary, (G) neurovascular, (H) oncology, (I) portal, (J) pediatric, (K) guideline development, and (L) clinical trials.

treatment more so than arterial interventions. While the role of interventional radiologists in treating peripheral arterial disease has expanded, obtaining training in this domain has remained difficult.

Quality guideline developments have continued to comprise a small proportion of the total publications throughout the journal's history accounting for on average 1% of the total publications in the journal throughout its history. Although there was not a statistically significant increase in the number of quality guideline developments over the journal's history, the conclusions drawn

from these forms of scholarly activities contribute significantly toward improving patient outcomes and safety.<sup>17</sup> Finally, the results displayed in Figure 5 appear to indicate that as the research output of *JVIR* has increased, so too has the medical community's awareness of the expanding role of interventional radiology as indicated by the nearly uniform increase in annual citations in each content category.

Changes in the geographic distribution of research output provides insight into the regions that have been consistently productive,

and draws attention to areas that appear to be underrepresented in *JVIR*. Internationally, the United States accounted for 90% of the total publications during the first 5 years of the journal while it now accounts for 56% of the total publications over the last 5 years. This is in line with previous results detailing the increased international representation of interventional radiology research over time, with a predominate shift from articles written in the United States to those written in Western Europe and Asia.<sup>8,18</sup> In particular, the research output in Canada, Japan, and South Korea have noticeably increased (Fig 3). Institutions located in South America, Africa, and much of Asia remain underrepresented. Although not detectable on the heat map, these regions have contributed to *JVIR* throughout its history. Within the United States, *JVIR* has received most of its contributions from the Northeast and the West Coast regions of the United States. This trend has been relatively constant throughout the journal's history. Particular regions within the Midwest have fluctuated greatly over time. These changes may be due to the migration of productive authors from one institution to another. In addition, there are regions that have been consistently underrepresented, including the Southwest, Southeast, and the Rocky Mountain region. With these trends in mind, *JVIR* has proven to be an internationally recognized journal, with increased representation from authors around the world.

One limitation of this study is related to the depiction of the heat map. We were only able to represent the top 100 institutions by *JVIR* research for each time period, which led to areas of less output to be left out of the geographic display. Although accounted for in our total summary of publications, these regions do not appear on the heat map. Additionally, content analysis was conducted using a variety of related keywords, and while the keyword search captured 74.6% of *JVIR* articles, a portion of articles were not categorized using this method. Another limitation is that this study only encapsulates the body of research published by the *JVIR* and not all research published within interventional radiology. Further, it also only includes the research that was accepted for publication and ultimately printed and does not reflect the entire body of publications or research being submitted to the journal. As such, there may have been some bias toward specific types of content based on decisions made by the editorial team at various times during the history of the journal. While speculative, there may be a bias in the editorial decision-making process toward particular institutions, which may have led to the underrepresentation of other institutions vying for publication.

Our study demonstrates that the *JVIR* has shown continued growth since its inception and has strengthened its international reputation with more global research than ever before. Publications related to oncologic, arterial, and venous interventions have

comprised a large portion of the recent publications and reflect the increasing interest in these fields. As the official journal of the Society of Interventional Radiology, the state of the *JVIR* is healthy with an equally as robust trajectory for the future.

### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1067/j.cpradiol.2018.05.002](https://doi.org/10.1067/j.cpradiol.2018.05.002).

### References

1. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography: a new technique. *Acta Radiol* 1953;39:368–76.
2. Boijesen E, Folin J. Angiography in carcinoma of the renal pelvis. *Acta Radiol* 1961;56:81–93. os-56.
3. Boijesen E, Feinstein GL. Arteriographic catheterization techniques. *Am J Roentgenol Radium Ther Nucl Med* 1961;85:1037.
4. Smith TP. *JVIR* celebrates 25 years of innovation. Part 1: 1989–1995. *J Vasc Interv Radiol* 2015;26:980–3.
5. Luukkonen T. Bibliometrics and evaluation of research performance. *Ann Med* 1990;22:145–50.
6. Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. *Pharmacotherapy* 2015;35:551–9.
7. Chen MY, Jenkins CB, Elster AD. Internationalization of the American Journal of Roentgenology: 1980–2002. *Am J Roentgenol* 2003;181:907–12.
8. Ray CE, Gupta R, Blackwell J. Changes in the American Interventional Radiology Literature: comparison over a 10-year time period. *Cardiovasc Intervent Radiol* 2006;29:599–604.
9. NRMP Results and Data Specialties Matching Service 2013–2017. National resident matching program; 2017 p. 25.
10. Chen JY, Agarwal V, Orons PD. Competitiveness of the match for interventional radiology and neuroradiology fellowships. *J Am Coll Radiol* 2014;11:1069–73.
11. Tognolini A, Louie JD, Hwang GL, et al. Utility of C-arm CT in patients with hepatocellular carcinoma undergoing transhepatic arterial chemoembolization. *J Vasc Interv Radiol* 2010;21:339–47.
12. Ahmed M, Solbiati L, Brace CL, et al. Image-guided tumor ablation: standardization of terminology and reporting criteria—a 10-year update. *J Vasc Interv Radiol* 2014;25:1691–705. e4.
13. Healey TT, March BT, Baird G, Dupuy DE. Microwave ablation for lung neoplasms: a retrospective analysis of long-term results. *J Vasc Interv Radiol* 2017;28:206–11.
14. Ziemlewicz TJ, Hinshaw JL, Lubner MG, et al. Percutaneous microwave ablation of hepatocellular carcinoma with a gas-cooled system: initial clinical results with 107 tumors. *J Vasc Interv Radiol* 2015;26:62–8.
15. Sacco R, Bargellini I, Bertini M, et al. Conventional versus doxorubicin-eluting bead transarterial chemoembolization for hepatocellular carcinoma. *J Vasc Interv Radiol* 2011;22:1545–52.
16. Kallini JR, Gabr A, Salem R, et al. Transarterial radioembolization with yttrium-90 for the treatment of hepatocellular carcinoma. *Adv Ther* 2016;33:699–714.
17. Brown DB, Nikolic B, Covey AM, et al. Quality improvement guidelines for transhepatic arterial chemoembolization, embolization, and chemotherapeutic infusion for hepatic malignancy. *J Vasc Interv Radiol* 2012;23:287–94.
18. Lim KJ, Yoon DY, Yun EJ, et al. Characteristics and trends of radiology research: a survey of original articles published in *ajr* and radiology between 2001 and 2010. *Radiology*. 2012;264:796–802.