

RESEARCH ARTICLES

Identification of milestone papers in physics via reference publication year spectroscopy

Yu Liao^{a,b}, Zhesi Shen^{a*}, Liying Yang^a

a. National Science Library, Chinese Academy of Sciences, Beijing, China

b. Department of Library, Information and Archives Management School of Economics and Management, University of Chinese Academy of Sciences, Beijing, China

ABSTRACT

In the modern time of the high speed development of physics, the citation analysis facilitates us to trace the brilliant ideas and works in the past. Here we use the Reference Publication Year Spectroscopy (RPYS) to identify the historical roots that announce significant discoveries in physics and compare them with the milestone papers selected by physicists. Among the 123 milestones, 64 milestone papers are successfully identified by RPYS. Some papers are identified simultaneously in multiple subfields, implying their broad impact across the fields of physics. The RPYS analysis shows promise in detecting the historical roots and identifying fundamental papers. There are still some open questions that need to be investigated.

KEYWORDS

Reference Publication Year Spectroscopy; RPYS; Milestone Papers; Citation Analysis

1 Introduction

In the past decades, we have witnessed the exponential growth of publications and the great achievements in physics ranging from Higgs boson in micro scale to gravitational wave in large scale. With the citation data becoming more available and citation analysis approaches and tools being developed, we can efficiently trace the idea flows to the breakthroughs that significantly boost the advancement of physics via the citation links. Detecting these historical roots plays important roles in providing insights for understanding the context of knowledge creation and guidance for future directions of development. Redner (2005) analysed the citation statistics of publications from 110 years of Physical Review series and the citation patterns of highly-cited papers. Khelfaoui and Gingras (2019) turn to a journal-level perspective and quantitatively analyse the changing position of Physical Review from the periphery to the center of the physics journal citation network among its more than 120 years history.

Among the citation analysis approaches, the recently proposed reference publication year spectroscopy (RPYS) method (Marx & Bornmann, 2014) aiming at exploring the historical roots, attracts scholars' attention. RPYS investigates the yearly distribution characteristics of

*corresponding author: shenzhs@mail.las.ac.cn

the cited references of a set of publications in a pre-selected field (Comins & Hussey, 2015). RPYS has been hitherto applied by some researchers to identify milestone works in several research fields and topics, e.g., Graphene and solar cells (Marx et al., 2014), Darwin Finches (Marx & Bornmann, 2014), Higgs Boson (Barth et al., 2014), IMetrics (Leydesdorff et al., 2014), Philosophy of Science (Wray & Bornmann, 2015), Global Positioning System (GPS) (Comins & Hussey, 2015), Knowledge Management (Khasseh & Mokhtarpour, 2016), Tribology (Elango et al., 2016), Information and Library Science (Comins & Leydesdorff, 2017), Citation analysis (Hou, 2017), Depression Prevention (Geraei et al., 2018), Carotid Artery Stenting (Yeung, 2020), Critical Social Psychology (Millán et al., 2020), Ecological Economics (Ballandonne, 2019), Health Equity (Yao et al., 2019), Positive Psychology (Khademi & Najafi, 2018). In addition, easily and user-friendly tools are also developed by Leydesdorff (www.leydesdorff.net/software/rpys), Thor (CRExplorer, www.crexplorer.net), Comins (<http://comins.leydesdorff.net>).

In the exploration work of many predecessors, we find that the application scenarios of RPYS are mainly on small subject areas. So if you want to expand this method, there are two key questions: What if there is no way to determine the subject search terms? What to do if RPYS is applied to a large field? To solve the first problem, Some researchers apply marker paper to reveal the most important works for the relevant community, and all papers co-cited with the marker paper are analyzed using RPYS (Haunschild & Marx, 2020; Scheidsteger & Haunschild, 2020). Various sampling methods are used to solve the second problem. Haunschild et al. (2020) concluded that the cluster sampling performs worst and the systematic sampling performs best. The random sampling also performs very well but not as well as the systematic sampling. But still there are some differences between part RPYS (sampling spectrogram) and full RPYS (population spectrogram), because the loss of data will lead to the overall deviation. More importantly, in this paper we propose a new method to apply RPYS on whole physics data set. We use Physics and Astronomy Classification Scheme (PACS) codes to divide the whole data set into several small units, each of which can exist as a subject independently, and is analyzed using RPYS.

In addition, although RPYS has shown promising potential in identifying seminal works, in most of the exploration works, the authors consider themselves also as experts to interpret the results, resulting to the validation of RPYS less objective. Bornmann et al. (2018) compared RPYS's performance with independent expert-opinion in the research topic of basal cell carcinoma. In this work, we attempt to apply RPYS analysis in the discipline of physics and evaluate its performance against milestones selected by experts.

2 Data and Methods

APS dataset. In this work we use the papers published in American Physical Society (APS) journals to test the effectiveness of RPYS in identifying milestone papers. The APS publish the famous Physical Review journal series, e.g., Phys. Rev. Lett., A, B, C, D and E, covering almost all areas of physics. The data set was directly provided by APS under request, with a total of more than 550,000 articles. The publication year was from 1894 to 2015, and the articles and their references formed nearly 7 million citations. *Milestone papers.* In 2008 to celebrate the 50th anniversary of Phys. Rev. Lett., one of the most prestigious physics journals, a collection of Milestone Letters that "have made long-lived contributions to physics, either by announcing significant discoveries, or by initiating new areas of research" are selected by the

APS editors. These milestone letters are further used as a part of golden standard to validate the performance of RPYS. For details of the milestone letters, please see PRL¹. Later, in 2020, as part of the celebration of the 50th anniversary of Physical Review A, Physical Review B, Physical Review C, and Physical Review D, their editors started a collection of milestone papers which has made important contributions to specific field like atomic, condensed matter physics, nuclear physics, particle physics and so on. These selected milestone papers form the other part of golden standard to validate the performance of RPYS. For details of the milestone papers, please see the websites of PRA², PRB³, PRC⁴ and PRD⁵. In total 230 milestone papers are selected by experts.

PACS codes. Physics and Astronomy Classification Scheme (PACS) codes is a classification system of fields in physics. One PACS code consists of 6 digits encoding a hierarchical structure of physics from broad fields to specific topics, e.g. 05.10.Gg. For each APS paper, about 3 codes are assigned to represent its corresponding research topics. In this work, we used the first 2 digits to categorize the papers into categories focusing on similar research topics. In each categorize, we use RPYS to identify and validate the milestone papers. As the PACS codes started from the early 1980s, we only included papers published ranging from 1985 to 2013 in our analysis. There are a total of 123 milestone papers with PACS codes, and each milestone paper will be put in one or several categories based on the assigned PACS codes.

RPYS. RPYS analysis is based on the reference publication year analysis and the procedure can be briefly described into four steps. 1) Gather related publications together with their references from an interested research topic or area. Such set can be established via search-

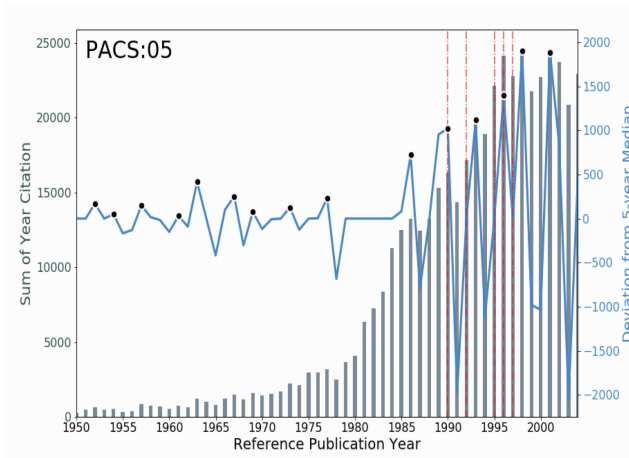


Figure 1 Example of RPYS analysis on the field of PACS-05. Gray bars represent the citations of each reference publication year, blue solid line represents the deviation within a five-year time window, black dots represent the selected peak years and red dashed lines highlight the publication year of milestones in gold standard.

¹ <https://journals.aps.org/prl/50years/milestones>

² <https://journals.aps.org/prl/50th>

³ <https://journals.aps.org/prb/50th>

⁴ <https://journals.aps.org/prc/50th>

⁵ <https://journals.aps.org/prd/50th>

ing for some keywords. Here we use the PACS codes to construct our analyzing publication set. 2) Aggregate the cited references according to their published years to form a *total citation v.s. reference publication year* plot. 3) Calculate the deviation of number of cited references in one reference publication year compared with that of previous and following two years. Large positive deviation implies important publications are published in that year. 4) Select the years with large deviation as peak years based on some criteria, and then select the top cited publications within these peak years as milestones. Here for simplicity, we use absolute peak criterion to select the peak years. Figure 1 shows the RPYS analysis on the publications belonging to PACS:05. The gray bars represent reference publication year distribution, and the blue line represents the deviation within a five-year time window. The black dots indicate the selected peak years. The top 10 highly cited references in each peak year are selected as key publications and will be further compared with the milestones selected by experts.

3 Results

The performance of applying RPYS on the APS dataset is shown in Table 1. Among the 123 milestones, in total, 64 milestone papers are successfully identified by RPYS and the identification rate is 52%. Diving into each PACS category (see Table 1), we found that the category of PACS-76 and 96 achieved 100% identification rate. However, there are 11 PACS categories that fail to identify any milestone which is in the category, e.g., PACS-06(metrology, measurements, and laboratory procedures), 07(Instruments, apparatus, and components common to several branches of physics and astronomy), 24(nuclear reactions), 29(experimental methods and instrumentation for elementary-particle and nuclear physics) and 33(molecular properties and interactions with photons).

Table 1 The identification performance of RPYS in each PACS category. For each PACS category, the number of milestones in this category (N), the number of successfully identified milestones by RPYS (S_n) and identification rate (R) are presented among the 123 mile-

PACS	N	S_n	R	PACS	N	S_n	R
02	3	1	33.33%	61	3	1	33.33%
03	19	4	21.05%	63	1	0	0.00%
04	5	4	80.00%	64	1	0	0.00%
05	11	4	36.36%	67	2	1	50.00%
06	2	0	0.00%	68	3	1	33.33%
07	1	0	0.00%	71	16	1	6.25%
11	8	3	37.50%	72	8	2	25.00%
12	12	1	8.33%	73	12	1	8.33%
13	16	3	18.75%	74	6	1	16.67%
14	11	3	27.27%	75	9	4	44.44%
21	18	4	22.22%	76	1	1	100.00%
23	4	2	50.00%	77	3	1	33.33%
24	4	0	0.00%	78	6	1	16.67%
25	14	2	14.29%	81	2	1	50.00%
26	6	2	33.33%	82	1	0	0.00%
27	6	2	33.33%	84	2	0	0.00%

<i>PACS</i>	<i>N</i>	<i>Sn</i>	<i>R</i>	<i>PACS</i>	<i>N</i>	<i>Sn</i>	<i>R</i>
29	1	0	0.00%	85	3	1	33.33%
31	7	3	42.86%	87	1	0	0.00%
32	8	3	37.50%	89	6	2	33.33%
33	1	0	0.00%	95	6	1	16.67%
37	1	0	0.00%	96	1	1	100.00%
41	4	1	25.00%	97	6	3	50.00%
42	19	6	31.58%	98	3	2	66.67%

stone Among the 123 milestone papers, 38 milestone papers are simultaneously identified based on RPYS at least in 2 PACS categories, implying their broad impact across the fields of physics (see Table 2 (end of this paper)). For example, the milestone paper (doi:PhysRevB.54.11169) entitled "Efficient iterative schemes for ab initio total-energy calculations using a plane-wave basis set" authored by Kresse and Furthmüller (1996), emerges from 18 PACS categories, e.g. PACS-02(mathematical methods in physics), 31(electronic structure of atoms and molecules: theory), 61(structure of solids and liquids; crystallography), 71(electronic structure of bulk materials) , 81(materials science), and 85(electronic and magnetic devices; microelectronics)(see Table 3). As shown in Table 3, this milestone paper has a high citation in every PACS category. Especially in PACS-61, 68 and 71, it was cited more than 1000 times. The description of this milestone paper by PRB editor is as follows:

"Kresse and Furthmüller present an iterative matrix diagonalization scheme and a charge density mixing scheme for the determination of the electronic ground state of a condensed matter system within the Kohn-Sham density functional approach. Based on this and three other major publications by Kresse and colleagues from 1993 and 1996, the proposed techniques have been expertly built into the computational software now widely known and used as the Vienna Ab initio Simulation Package (VASP). The resulting flexible tool has enabled the reliable prediction of the electronic structure and other important ground-state properties of an impressive range of materials. The package is by far the most popular and widely used computer program for atomic-scale materials modeling."

In Table 3, we also noticed a paper (PhysRevLett.77.3865) revealed by RPYS but was not selected into milestone paper collections by experts. This paper authored by John P. Perdew, Kieron Burke and Matthias Ernzerhof, presents a simple derivation of a simple Generalized gradient approximations, in which all parameters (except those in local spin density (LSD)) are fundamental constants, has been cited more than 100,000 times in web of science .

Table 3 The citation performance of the milestone paper (PhysRevB.54.11169) in each PACS category. This milestone paper was revealed by RPYS in 18 categories. For these categories, we present the top 3 highly cited papers and their citations.

<i>PACS</i>	<i>DOI</i>	<i>Citations</i>	<i>Rank</i>	<i>PACS</i>	<i>DOI</i>	<i>Citations</i>	<i>Rank</i>
07	PhysRevD.53.6749	42	1	75	PhysRevLett.77.3865	1073	1
	PhysRevLett.77.3865	32	2		PhysRevB.54.11169	705	2
	PhysRevB.54.11169	20	3		PhysRevB.54.9353	465	3
31	PhysRevLett.77.3865	576	1	77	PhysRevB.54.11169	240	1
	PhysRevB.54.11169	246	2		PhysRevLett.77.3865	216	2
	PhysRevA.54.3948	90	3		PhysRevB.53.5047	36	3

PACS	DOI	Citations	Rank	PACS	DOI	Citations	Rank
61	PhysRevLett.77.3865	1454	1	78	PhysRevLett.77.3865	439	1
	PhysRevB.54.11169	1427	2		PhysRevB.54.11169	258	2
	PhysRevLett.76.2511	122	3		PhysRevLett.76.3005	212	3
63	PhysRevLett.77.3865	398	1	81	PhysRevLett.77.3865	514	1
	PhysRevB.54.11169	345	2		PhysRevB.54.11169	446	2
	PhysRevLett.77.3831	51	3		RevModPhys.68.1259	139	3
68	PhysRevLett.77.3865	1129	1	82	PhysRevLett.77.3865	282	1
	PhysRevB.54.11169	1103	2		PhysRevB.54.11169	233	2
	PhysRevLett.76.1675	113	3		PhysRevLett.77.1897	63	3
71	PhysRevLett.77.3865	3074	1	84	PhysRevLett.77.3865	27	1
	PhysRevB.54.11169	1860	2		PhysRevB.54.11169	25	2
	RevModPhys.68.13	1308	3		PhysRevLett.76.4773	12	3
72	PhysRevB.54.9353	311	1	85	PhysRevB.54.9353	229	1
	PhysRevLett.77.3865	306	2		PhysRevLett.77.3865	124	2
	PhysRevB.54.11169	205	3		PhysRevB.54.11169	74	3
73	PhysRevLett.77.3865	1201	1				
	PhysRevB.54.11169	928	2				
	PhysRevLett.77.3613	343	3				

There are 26 milestone papers identified by RPYS program only in 1 PACS categories, which imply their irreplaceable impact in the specific fields of physics. Here we take some milestone papers for examples (see Table 4). From the corresponding relationship between the PACS column and the Contributions column in Table 4, we can find that these milestone papers have made irreplaceable impetus to these corresponding fields, and promoted the rapid development of these fields.

Table 4 The example of milestone paper, which has great influence on some specific field of physics. For each milestone paper the doi, PACS category that revealed this milestone paper, Contribution described by the corresponding journal editors, Citations within the specific PACS category, and ranking of the paper based on citations in each PACS category are presented.

DOI	PACS	Contribution	Citations	Rank
PhysRevA.38.3098	31 (Electronic structure of atoms and molecules: theory)	This paper introduces a gradient –corrected exchange –energy functional that reproduces the exact asymptotic behavior of finite many–electron systems. This functional marks an important development in density functional theory with far–reaching applications in atomic and condensed matter physics, chemistry, and materials science.	269	1
PhysRevB.39.4828	75 (Magnetic properties and materials)	The work involves the discovery of a much more pronounced effect – giant magnetoresistance; The 2007 Nobel Prize in Physics was awarded to Albert Fert and Peter Grünberg “ for the discovery of Giant Magnetoresistance.”	356	2

DOI	PACS	Contribution	Citations	Rank
PhysRevC.58.1671	25 (Probability theory, stochastic processes, and statistics)	This paper provided a strategy and the techniques for analyzing anisotropic flow in relativistic nuclear collisions. Nearly all theoretical and experimental researchers in this field are guided by this analysis in investigating the high-temperature matter created in such collisions.	175	1
PhysRevD.56.3258	98 (Stellar systems; interstellar medium; galactic and extragalactic objects and systems; the Universe)	In this paper, the authors provide an expansive and detailed fundamental theory of reheating, which includes several different phases dubbed preheating. But with this paper the authors provided the basis for every model of reheating to this day.	286	1
PhysRevLett. 58.1490	97 (Stars)	This paper reported the observation in two large underground water Cherenkov detectors of neutrinos associated with the supernova 1987A. The observation of the neutrinos helped confirm the understanding of the physics of supernovae, provided limits on the neutrino rest mass and other properties and ushered in a new era of neutrino astronomy.	136	1
PhysRevLett. 61.2472	72 (Electronic transport in condensed matter)	The involves the discovery of a much more pronounced effect – giant magnetoresistance; The 2007 Nobel Prize in Physics was awarded to Albert Fert and Peter Grünberg ” for the discovery of Giant Magnetoresistance.”	324	1

4 Conclusion and Discussion

In this work, we investigate the RPYS analysis and its application in identifying milestones in the field of physics. Comparing with the golden standards selected by experts, 64 out of 123 milestones are successfully identified (52% identification rate) from 46 PACS categories in total. However the success rates across the fields of physics show large difference. The remaining 59 milestone papers are not identified in any of the PACS categories by RPYS. Going through these 59 papers in detail, we find that there are two main reasons why the RPYS program can not identify milestone papers selected by experts. One is the publication year of milestone papers fail to appear in peak years. In RPYS analysis, peak year selection is a fundamental step, and here we use the absolute peak criterion, which needs the current deviation being larger than both sides. The second is that there are not enough citations in the field defined by PACS codes. In the program of RPYS, if a reference publication year is determined, we will use these papers citations to rank in this year. So if a milestone paper selected by field experts fails to accumulate enough citations, it can not emerge out from those papers which get more citations. The reference years of these 9 milestones all failed in satisfying this criterion. Despite of being not in the peak years, the citation counts of 5 milestones

are not high enough to be ranked in top 10. The citations of a paper in this context is determined by publication years and the division of the fields. In our work, the publication year of milestone papers arrange from 1985 to 2013, and the data set from 1894 to 2015, so part of milestone papers have not enough time to accumulate citations in our data set.

The RPYS analysis shows promise in detecting the historical roots and identifying fundamental papers. There are still some open questions that need to be investigated. In the PRYS analysis, cited references are gathered and compared based on their publication years, while there is a huge difference in citation time to accumulate citations between articles published in January and articles in December of the same year. Mariani et al. (2016) pointed that comparing the target paper i within a relative publication window $[i-\Delta/2, i+\Delta/2]$ centered on paper i is better than comparing within an absolute year. It will be an open question of how to modify RPYS in a relative reference time instead of year. In addition, it is important to compare the performance of RPYS with other citation-based approaches.

Acknowledgements

We thank Jinshan Wu for useful discussions. This work is supported by the National Natural Science Foundation under Grant 71974017 and 72074030.

Author Contributions

Conceptualization: SZ

Data Curation: LY, SZ

Formal analysis: LY, SZ

Methodology: LY, SZ

Writing – original draft: YL, SZ

Writing – review & editing: SZ, LY, YL

Supervision: YL

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Reference

- Ballandonne, M.(2019). The historical roots(1880–1950) of recent contributions(2000–2017) to ecological economics: insights from reference publication year spectroscopy. *Journal of Economic Methodology*, 26 (4), 307–326.
- Barth, A., Marx, W., Bornmann, L., & Mutz, R.(2014). On the origins and the historical roots of the Higgs boson research from a bibliometric perspective. *European Physical Journal Plus*,129.
- Bornmann, L., Haunschild, R., & Leydesdorff, L.(2018). Reference publication year spectroscopy (RPYS) of Eugene Garfield's publications. *Scientometrics*, 114, 439–448.
- Comins, J. A., & Hussey, T. W.(2015). Detecting seminal research contributions to the development and use of the global positioning system by reference publication year spectroscopy. *Scientometrics*, 104, 575–580.
- Comins, J. A., & Leydesdorff, L.(2017). Identification of long-term concept-symbols among citations: do common intellectual histories structure citation behavior?. *Journal of the Association for Information Science and Technology*, 68 (5), 1224–1233.
- Elango, B., Bornmann, L., & Kannan, G.(2016). Detecting the historical roots of tribology research: a bibliometric analysis. *Scientometrics*, 107, 305–313.

- Geraei, E., Shakibaei, F., & Mazaheri, E.(2018). Depression: Detecting the historical roots of research on depression prevention with reference publication year spectroscopy. *International Journal of Preventive Medicine*, 9 (1), 53.
- Haunschild, R., Marx, W.(2020). Discovering seminal works with marker papers. *Scientometrics*, 125, 2955–2969.
- Haunschild, R., Marx, W., Thor, A., & Bornmann, L.(2020). How to identify the roots of broad research topics and fields? the introduction of rpys sampling using the example of climate change research. *Journal of Information Science*, 46 (3), 392–405.
- Hou, J.(2017). Exploration into the evolution and historical roots of citation analysis by referenced publication year spectroscopy. *Scientometrics*, 110, 1437–1452.
- Khademi, R., & Najafi, M.(2018). Tracing the historical roots of positive psychology by reference publication year spectroscopy(rpys): a scientometrics perspective. *Current Psychology (New Brunswick, N.J.)*, 39 (1), 438–444.
- Khasseh, A. A., & Mokhtarpour, R.(2016). Tracing the historical origins of knowledge management issues through referenced publication years spectroscopy (RPYS). *Journal of Knowledge Management*, 20,1393–1404.
- Khelifaoui, M., & Gingras, Y.(2019). Physical review: From the periphery to the center of physics. *Physics in Perspective*, 21, 23–42.
- Kresse, G., & Furthmüller, J.(1996). Efficient iterative schemes for ab initio total–energy calculations using a plane–wave basis set. *Physical review. B Condensed matter*, 54 (16), 11169–11186.
- Leydesdorff, L., Bornmann, L., Marx, W., & Milojevic, S.(2014). Referenced Publication Years Spectroscopy applied to iMetrics: Scientometrics, Journal of Informetrics, and a relevant subset of JASIST. *Journal of Informetrics*, 8, 162–174.
- Mariani, M. S., Medo, M., & Zhang, Y. C.(2016). Identification of milestone papers through time–balanced network centrality. *Journal of Informetrics*, 10, 1207–1223.
- Marx, W., & Bornmann, L.(2014). Tracing the origin of a scientific legend by reference publication year spectroscopy(RPYS): the legend of the Darwin finches. *Scientometrics*, 99, 839–844.
- Marx, W., Bornmann, L., Barth, A., & Leydesdorff, L.(2014). Detecting the historical roots of research fields by reference publication year spectroscopy (RPYS). *Journal of the Association for Information Science and Technology*, 65, 751–764.
- Millán, J. D., Cudina, J. N., Ossa, J. C., Vega–Arce, M., Scholten, M., & Salas, G.(2020). Academic networks of critical social psychology in brazil. An analysis of the impact and the intellectual roots. *Current Psychology (New Brunswick, N.J.) (SPE)*.
- Redner, S.(2005). Citation statistics from 110 years of physical review. *Physics Today*, 58, 49–54.
- Wray, K. B., & Bornmann, L.(2015). Philosophy of science viewed through the lense of “Referenced Publication Years Spectroscopy”(RPYS). *Scientometrics*, 102, 1987–1996.
- Scheidsteger, T., & Haunschild, R.(2020). Telling the story of solar energy meteorology into the satellite era by applying(co–citation) reference publication year spectroscopy. *Scientometrics*, 125, 1159–1177.
- Yao, Q., Li, X., Luo, F., Yang, L., & Sun, J.(2019). The historical roots and seminal research on health equity: a referenced publication year spectroscopy (rpys) analysis. *International Journal for Equity in Health*, 18 (1), 152.
- Yeung, W.(2020). The historical roots of carotid artery stenting literature: An analysis of cited references. *Current Science*,119, 447–450.

[illegible]

PAOS	27			29			31			32			38			37			41			42			61			63			64			67			68			71			72																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
	Year																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	doi																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	PhysRevB.31.805	1985	Y		N	2	23	N	13	29	N	1	439	N	2	124	N	1	31	N	4	253	Y	191	4	Y	5	139	N	2	682	N	2	682	N	4	88	N	4	88	N	4	88	N	4	88	Y	62	10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	PhysRevLett.55.48	1985	Y		N	2	23	N	13	29	N	1	439	N	2	124	N	1	31	N	4	253	Y	191	4	Y	5	139	N	2	682	N	2	682	N	4	88	N	4	88	N	4	88	N	4	88	Y	62	10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
	PhysRevB.34.5390	1986	N		N			N	61	4	N	3	315	N	17	4	N	1	90	N	23	75	N	59	17	N	12	38	Y	8	276	N	1	223	Y	40	35	N	630	1	N	43	15																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	PhysRevLett.56.930	1986	N		N			N	1	384	N	2	388	N	1	230	N	4	30	N	12	137	N	101	6	N			Y	4	481	N	2	147	Y	153	5	N	19	182	N	3	483																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	PhysRevLett.58.1490	1987	Y		N	2	30	N			N			Y			N			Y			N		N			N										N		N	N	N	N	N	N	N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevLett.58.1494	1987	Y		N	1	58	N			N			Y			N			Y			N		N			N										N		N	N	N	N	N	N	N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevC.35.2252	1987	Y	3	200	N		N			N			Y			N			Y			N		N			N										N		N	N	N	N	N	N	N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevC.36.2026	1987	Y	12	41	N		N	3	171	N			Y			N			Y			N		N			N										N		N	N	N	N	N	N	N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevLett.58.908	1987	Y			N		N	3	171	N			Y	3	86	N			Y	1	657	N	44	18	N	16	26	N	12	168	N	2	137	N	9	249	N	62	28	N	24	47																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	PhysRevB.37.3759	1988	N			N		N	Y	6	104	Y		N	1	242	N			N	2	538	N	8	354	N	12	40	N	11	169	N	5	86	N	4	483	N	527	1	Y	46	20																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	PhysRevC.38.1010	1988	N	18	14	N		N	Y	1	422	Y		N			N			N			N		N			N												N	1	1931	Y																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	PhysRevLett.61.169	1988	N			N	2	32	Y			Y	101	4	N	6	37	N	12	4	1	87	N	65	13	N			N										N	1	979	N			Y	1	926																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	PhysRevLett.61.2472	1988	N			N			Y	6	104	Y		Y			N			N			N		N			N												N	81	8	N	98	17	Y	324	1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	PhysRevLett.61.826	1988	N			N	1	62	Y			Y	155	1	N	6	37	N	18	1	N	142	3	N			N			N	4	482	N	9	51	N			N	1	1931	Y																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
	PhysRevA.38.3098	1988	N			N			Y	269	1	Y	27	42	N	37	1	N	1	37	N	15	140	N	203	3	N	25	11	N	34	26	N	2	165	N	90	5	N	425	2	Y	29	48																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	PhysRevB.37.785	1988	N	1	338	N			Y	219	2	Y	28	39	N	30	3	N	1	37	N	23	81	N	210	2	N	21	18	N	33	30	N	2	165	N	110	4	N	322	3	Y	28	52																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	PhysRevB.38.6084	1988	N			N			Y	1	422	Y		Y			N			N			N	34	40	N			N	1	1042	N							N	77	9	N	23	174	Y	5	350																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	PhysRevB.39.4828	1989	N			N			N	6	100	N			N			N			N	2	555	N	22	90	Y			Y	7	303	Y							N	37	30	N	46	70	N	160	1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	PhysRevB.40.546	1989	N			N			N	2	292	N			N	2	142	N			N	79	18	N	24	77	Y	5	155	Y	152	3	Y	362	1					N	13	162	N	176	12	N	48	19																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	PhysRevLett.63.1950	1989	N			N			N	10	132	N	2	142	Y			N	34	2	N	81	17	N	10	268	Y	7	104	Y										N	1	1092	N	34	108	N	2	705																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
	PhysRevLett.64.1196	1990	Y			N			N	2	437	N			1	223	N			N	2	63	N	73	19	N	1	1511	N									Y	1	1088	Y			N	3	563																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevLett.64.821	1990	Y			N			N			N			N			N			N	78	18	N	2	1102	N			N	9	235	N						Y	1	1088	Y			N	3	563																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	PhysRevC.41.1147	1990	Y	116	1	N	11	3	N	3	201	N		N	4	288	N			N	1	909	N			N			N											Y	2	1593	N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	PhysRevLett.67.2295	1991	N			Y	1	70	N			N	20	71	N		N	50	2	N	152	5	N	4	766	N	3	241	N											N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2	149	N	2

PAOS		27			29			31			32			33			37			41			42			61			63			64			67			68			71			72																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
doi		P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
PhysRevC.52.P23 PhysRevLett.74.2626 PhysRevLett.74.2632 PhysRevLett.75.3969 PhysRevC.51.38 PhysRevA.52.3457 PhysRevA.52.P2493 PhysRevLett.77.420 PhysRevB.54.9353 PhysRevB.54.11169 PhysRevC.53.2086 PhysRevD.56.3258 PhysRevA.55.4318 PhysRevB.55.1142 PhysRevD.55.5112 PhysRevLett.78.2690 PhysRevB.58.P10096 PhysRevC.58.1671 PhysRevC.58.1804 PhysRevLett.81.1562 PhysRevA.57.120 PhysRevD.59.084006 PhysRevLett.83.3370 PhysRevLett.83.4690 PhysRevD.62.064015 PhysRevLett.84.4184 PhysRevLett.85.3966 PhysRevA.62.062314 PhysRevB.61.14095 PhysRevC.62.054311 PhysRevLett.84.3232 PhysRevLett.84.5102 PhysRevB.63.245407 PhysRevD.63.114020 PhysRevLett.87.071301 PhysRevC.63.024001 PhysRevA.65.022314 PhysRevB.65.165401 PhysRevD.66.106006 PhysRevA.65.032314 PhysRevB.65.195104 PhysRevLett.89.011301	1995	Y	28	12	N			N			N	2	49	N	37	4	Y	456	1	Y	37	7	Y	59	2	Y	1	105	N	6	50	N	268	3	N	5	719	N	2	348	Y	41	12	N	281	1	N	7	329	N	71	29	N	3	642																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
		1995	Y			N			N			Y	2	650	Y			N			N	1	1286	N			N			N			N			N			N			N			N			N	2	1945	N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		1995	Y			N			N			Y			Y			N			N			N			N			N			N			N			N			N			N			N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		1995	Y			N			N			Y			Y			N			N			N			N			N			N			N			N			N			N			N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		1995	Y	117	1	N	4	23	N	23	23	Y			Y	1	105	N	6	50	N	268	3	N	5	719	N	2	348	Y	41	12	N	281	1	N	7	329	N	71	29	N	3	642																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
		1995	Y			N			N	2	385	Y	39	31	Y	5	89	Y	8	22	N	1	206	N	86	24	N			N			N			N			N			N			N			N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		1995	Y			N			N	2	385	Y	20	96	Y	6	77	Y	1	105	N	104	18	N			N	1	573	Y	3	755	N	4	98	N			N			N			N			N			N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
		1996	N			N			N	Y	6	132	N	77	7	N	5	95	N	3	34	Y	1	241	Y	26	134	Y			Y			N	2	946	Y	105	2	Y	8	784	Y	1	1299																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
		1996	N			N			Y			N			Y			Y			Y			Y			Y	4	825	Y	1	607	N	2	940	2	Y	13	47	Y	1103	2	Y	1860	2	Y	205	3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
		1996	N	9	96	N			N	Y	3	260	N			N			Y			Y			Y			Y			Y			N	340	2	Y	13	47	Y			Y			Y			N			N			N			N																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
		1997	N			N			N			N			N			N			N			N			N			N			N			N	3	679	N	1	301	N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N			N	

[illegible]

PACS		73			74			75			76			77			78			81			82			84			85			87			89			95			96			97			98				
ddl	year	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R	P	C	R					
PhysRevC.66.064001	2002	N			N			N			Y			Y			Y			Y			Y			N			Y			N			Y			N			N			N							
PhysRevC.68.041001	2003	N			N			N			N			N			N			N			N			N			N			N			N			N			N			N							
PhysRevA.68.022312	2003	N	8	646	N			N	14	359	N	1	512	N			N			N			N			N			N			N			N			N			N			N							
PhysRevB.67.180401	2003	N	5	957	N	5	609	N	60	20	N	4	161	N	47	1	N	7	354	N	1	877	N			N			N			N			N			N			N			N							
PhysRevC.68.014313	2003	N			N			N			N			N			N			N			N			N			N			N			N			N			N			N							
PhysRevD.68.046005	2003	N			N	1	1320	N			N			N			N			N			N			N			N			N			N			N			N			N							
PhysRevD.69.103501	2004	N			Y			N			N			N			N			N			N			N			Y	1	769	N			N			Y	161	1	N	18	45	1	76	N	2	135	N	195	3
PhysRevA.70.013603	2004	N	28	128	Y	25	111	N	26	129	N			N			N	3	915	N			N			N			Y			N			N			Y			N			Y	322	1					
PhysRevB.71.014113	2005	Y	6	986	N	2	1104	Y	50	28	Y	2	318	Y	54	7	Y	15	134	N	2	471	N			Y			N	1	927	Y			N			Y			N			N							
PhysRevC.72.014904	2005	Y			N			Y			Y			Y			Y			Y			N			Y			Y			N			Y			N			N			N							
PhysRevC.72.055502	2005	Y			N			Y			Y	1	573	Y			Y			Y			N			Y			Y			N			Y			N			N			N							
PhysRevA.71.052108	2005	Y			N			Y			Y			Y			Y			Y			N			Y			Y			N			Y			N			N			N							
PhysRevB.71.045110	2005	Y	31	83	N	5	609	Y	38	48	Y			Y			Y			Y			N			Y			Y			N			Y			N			N			N							
PhysRevC.71.055202	2005	Y			N			Y			Y			Y			Y			Y			N			Y			Y			N			Y			N			N			N							
PhysRevB.73.125411	2006	N	290	3	N	16	143	N	36	52	N	6	74	N	4	134	N	47	9	Y	167	1	N	1	677	N	1	60	N	6	228	N			N			Y			N			Y							
PhysRevC.74.044602	2006	N			N			N			N			N			N			Y			N			N			N			N			N			Y			N			Y							
PhysRevD.73.072003	2006	N			N			N			N			N			N			Y			N			N			N			N			N			Y			N			Y							
PhysRevC.75.0205418	2007	N	176	6	N	9	268	N	8	531	N	2	284	N	9	46	N	54	4	N	72	3	N	1	621	N		N	4	304	N			N			Y	31	16	N			Y								
PhysRevB.76.045302	2007	N	370	2	N	63	6	N	69	11	N	1	474	N	3	136	N	19	56	N	4	248	N	1	621	N		N	48	7	N			N			Y			N			N								
PhysRevB.78.195424	2008	N	317	1	Y	50	70	Y	96	7	Y	2	323	N	3	139	Y	35	11	N	4	230	N			N			N	44	2	N	1	465	N			N			Y			Y							
PhysRevB.78.020503	2008	N	5	908	Y	257	8	Y	95	8	Y	22	10	Y			Y	22	37	N	5	181	N			N			N			N			N			N			Y			Y							
PhysRevC.77.054002	2008	N			Y			Y			Y			N			Y			N			N			N			N			N			N			N			Y	1	263	Y							
PhysRevA.79.053840	2009	N			N			N			N			N			N			N			N			N			N			N			N			Y			N			Y							
PhysRevB.80.245435	2009	N	34	58	N			N	1	2227	N			N			N	34	6	N	7	73	N	1	430	N		N						N			Y			N			Y								
PhysRevB.82.081101	2010	N	23	94	N	2	894	N	1	2027	N			N	1	206	N	4	394	N	5	78	N	2	150	N	2	15	N	1	665	N			N			N			Y			N							
PhysRevB.82.180520	2010	N	3	1065	N	176	4	N	50	9	N	14	8	N			N	22	12	N	1	593	N			N			N			N			N			N			N			Y							
PhysRevC.82.014903	2010	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevC.82.034330	2010	N	1	2028	N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevC.82.035804	2010	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevLett.105.136805	2010	N	59	15	N	4	582	N	15	112	N			N	1	206	N	31	6	N	9	23	N	1	342	N		N	4	205	N			N			N			N			N								
PhysRevA.84.025602	2011	N	6	405	N	5	388	N	2	1201	N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevB.83.195131	2011	N	19	68	N	2	770	N	3	844	N			N	1	174	N	2	514	N	10	5	N	3	46	N		N	2	265	N			N			N			N			Y								
PhysRevB.83.205101	2011	N	46	10	N	15	105	N	56	2	N	4	44	N	1	174	N	14	15	N	1	381	N			N			N	3	172	N			N			N			N			Y							
PhysRevC.83.061303	2011	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevC.84.024617	2011	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevD.83.084019	2011	N	1	1682	N			N	1	1775	N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevB.85.205302	2012	N	24	11	N	1	707	N	5	178	N			N			N	13	5	N	1	169	N	1	87	N		N			N			N			N			N			Y								
PhysRevC.87.034303	2013	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							
PhysRevC.88.025501	2013	N			N			N			N			N			N			N			N			N			N			N			N			N			N			Y							