



# Procalcitonin in general internal medicine: a bibliometric analysis

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**Background:** Procalcitonin (PCT) plays an important role in the identification of bacterial infection and therapy guidance. The relevant literature is mainly classified under critical care medicine or infectious disease. The research status of PCT in general internal medicine (GIM) is currently unclear. This research aimed to analyze PCT-related literature in the GIM field and provide references for future research.

**Methods:** A subject search strategy was used for the term PCT, with the search scope limited to Medicine, General & Internal. We conducted a search of relevant literature in the Science Citation Index Expanded (SCIE) database in the Web of Science Core Collection (WOSCC), with no publication date limit (1900 to May 16, 2021, the date of the final search for this study). The search results were analyzed using CiteSpace software to assess the status of PCT research in the GIM field based on annual paper publication numbers, the number of citations, country distribution, institution distribution, author distribution, journal distribution, and keyword usage.

**Results:** A total of 905 document records were retrieved. Articles were mainly from Europe, the United States, and China, and the number of citations totaled 15,917. There were 5 research institutions that published more than 10 related papers and 3 authors who published more than 10 papers. There was little cooperation between authors from different countries and institutions. This field should focus on leading journals in critical care medicine and quality comprehensive journals. Keyword analysis showed that the current research focus is the standardized application of PCT.

**Conclusions:** There are few targeted studies on the application of PCT in GIM, and the relevant important literature mainly comes from other journals. GIM-specific research should be increased in the future.

**Keywords:** Procalcitonin (PCT); general internal medicine (GIM); infection; bibliometrics

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## Introduction

General internal medicine (GIM) is receiving more and more attention from countries worldwide (1-3). GIM doctors are mainly general practitioners and are primarily responsible for the initial patient consultation, particularly for those patients with atypical or unclear symptoms. After initial diagnosis and treatment, some patients are cured, and others transfer to specialist departments for further

diagnosis and treatment (4). Consequently, in the medical systems of most countries, GIM and GIM physicians are at the forefront of disease diagnosis and treatment (5). During the current COVID-19 pandemic, many GIM doctors were infected because they were not sufficiently protected, and the losses were enormous (6).

In GIM, infectious diseases and unexplained fever are the most common problems, and clinical practice involves determining whether there is a possibility of bacterial

**Table 1** Document type analysis

Document type	Number of documents	%
Article	658	72.7
Review	93	10.3
Letter	61	6.7
Editorial material	55	6.1
Meeting abstract	30	3.3
Early access	14	1.5
Correction	7	0.8
Proceedings paper	2	0.2
News item	1	0.1
Retracted publication	1	0.1

infection and overseeing the use of antibacterial drugs (7). Procalcitonin (PCT) is a peptide precursor, produced by thyroid C cells. In some stress situations, such as sepsis and septic shock, the PCT level will increase, and the more severe the infection, the higher the patient's PCT level. PCT has high specificity and sensitivity in identifying bacterial infection and is recommended for both the identification of infection and monitoring of treatment (7). There are many studies on severe and secondary infection following viral infection; however, there is relatively little research based on GIM. The clinical significance of PCT in different environments may vary, and the evidence generated by research from different medical fields may not be applicable or well suited to other situations. A previous similar bibliometric analysis revealed that study of PCT mainly focused on respiratory infections, especially sepsis and pneumonia (8). This research aimed to understand the current research status and provide references for researchers by analyzing the overall situation of relevant documents classified in the GIM field.

## Methods

### Database

The Science Citation Index Expanded (SCIE) database in the Web of Science Core Collection (WOSCC) was used as the source for the literature search. SCIE, founded in 1957, is a bibliographic database published by the American Institute of Scientific Information. It contains the titles and citations of more than 8,000 important journals in the field

of natural sciences. SCIE is an important citation retrieval tool and an important basis for metrological research and scientific research evaluation.

### Search strategy

The method used in this study was subject search + limited search. The search term used for the subject search was PCT, and the limited search scope was Medicine, General & Internal. The publication date range was unlimited (from 1900 to the date of the last search of this study, May 16, 2021).

### Analysis method

We exported article and citation records obtained from the search results and used CiteSpace software to analyze the annual paper publication status, country, institution, author distribution, journal distribution, and keyword usage for PCT research in the GIM field.

### Statistical processing

This study primarily describes the current status of relevant indicators, and the main form of data presentation is the quantity (percentage) without comparative analysis.

## Results

### Literature search results

A total of 905 relevant research documents were obtained through the search, including 658 original articles, 93 reviews, 61 letters, 55 editorial materials, 30 meeting abstracts, 14 early access, 7 corrections, and 2 proceedings papers, 1 news item, and 1 retraction publication (the initial total number in *Table 1* is 922, 17 of which were classified repeatedly; the actual number of documents was 905). The distribution of the number of annual papers showed that the volume of research in this field is generally increasing year by year, with a relatively large increase in 2020, which might have been due to the COVID-19 pandemic in that year (*Table 2, Figure 1*). The citation frequency showed a more obvious trend of the increasing year by year, suggesting that related research is getting more and more attention. The number of citations for the papers was 15,917, the h-index was 50, and the average number of citations per paper was 17.59 (*Figure 2*).

**Table 2** Number of documents by publication year

Publication year	Number of documents	%
2021	61	6.7
2020	145	16.0
2019	92	10.2
2018	71	7.8
2017	72	8.0
2016	64	7.1
2015	57	6.3
2014	41	4.5
2013	51	5.6
2012	53	5.9
2011	41	4.5
2010	23	2.5
2009	24	2.7
2008	25	2.8
2007	22	2.4
2006	7	0.8
2005	10	1.1
2004	12	1.3
2003	3	0.3
2002	5	0.6
2001	8	0.9
2000	5	0.6
1999	4	0.4
1998	5	0.6
1997	2	0.2
1996	1	0.1
1993	1	0.1

### *Distribution of the literature in countries and institutions*

The articles were counted separately by country and institution, and CiteSpace V software was used to create a national visualization map (*Figure 3*) and an institutional visualization map (*Figure 4*). The results found that the top 5 countries for the number of papers published were China, the United States, Turkey, Switzerland, and Germany (*Table 3*). The top 5 countries for centrality were the

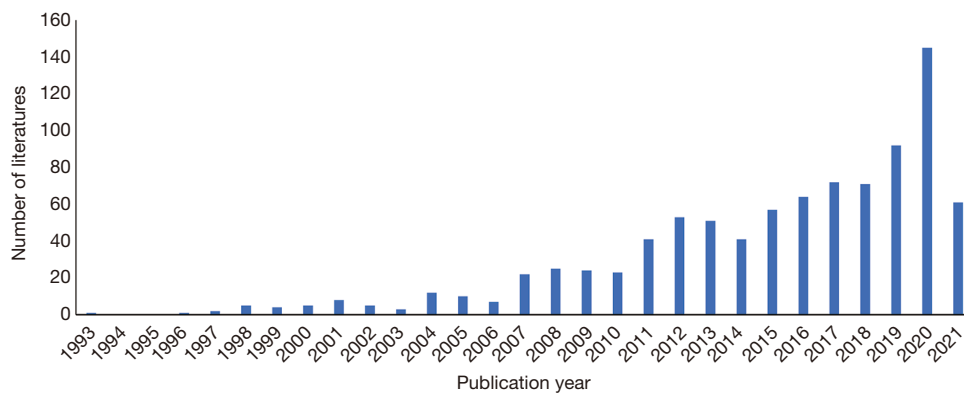
United States, Germany, the United Kingdom, Italy, and the Netherlands (*Table 4*). The top 5 institutions for the number of papers published were University Hospital Basel, the University of Basel, Kantonsspital Aarau, Huazhong University of Science and Technology, and Wuhan University (*Table 5*). All research institutions had a low centrality score, with only University Hospital Basel obtaining 0.02 and 6 other institutions 0.01 (*Table 6, Figure 4*). The centrality scores of other research institutions are all lower than 0.01, indicating that there is little cooperation between institutions in this field of research.

### *Author distribution*

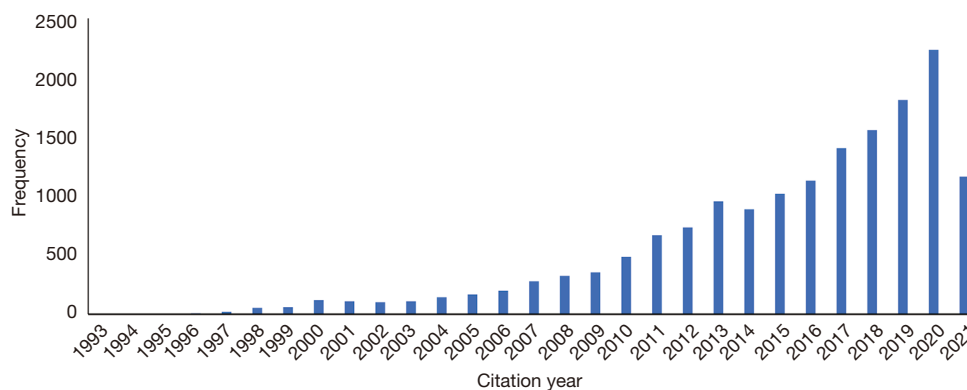
We performed statistical analysis on the number of papers published by the authors and the number of times they were cited and then created a visual map. The results showed that there were only three authors with more than 10 papers: B. Mueller, P. Schuetz, and M. Christ-Crain. In fact, according to the author information provided in the literature, the top 5 authors in *Table 7* were all from the University of Basel. However, in terms of cooperation status, only Mueller's centrality score reached 0.01, while the scores of all other authors were less than 0.01. Using data from the coauthored visualization map, it can be seen that the research work is relatively scattered, and authors from different research institutions have little cooperation with each other (*Table 7, Figure 5*). In terms of co-citation frequency, Schuetz has significantly more citations than the other authors. According to the information provided in the records, this is due to his frequent status as first author or corresponding author (*Table 8*). The co-citation centrality results show that M. Assicot has the highest score. Assicot's research was published relatively early, and initial research is often key to the field (*Table 9, Figure 6*).

### *Journal distribution*

Analysis of the distribution of the journals showed that the 905 articles retrieved in this study were from 126 journals, of which 6 journals had published more than 20 articles each in this field, accounting for a total of 222 journal articles (24.5% of the total number of articles) (*Table 10*). Judging from the frequency of citations and the results of centrality analysis, leading journals in critical care medicine and quality comprehensive journals are worthy of attention (*Tables 11,12*).



**Figure 1** Trends in the number of annual papers published.



**Figure 2** The annual trend of the number of citations for papers in this field.

### *Keywords reflect the research hotspots and frontiers in this field*

We used CiteSpace V software to draw a keyword co-occurrence map (Figure 7) and then analyzed the frequency and centrality of keywords (Tables 13,14). CiteSpace was used for burst detection of keywords with a high usage rate (Figure 8). The results showed that in this field, apart from PCT itself, the areas of research focus were sepsis, c reactive protein, infection, diagnosis, and mortality. Burst test results showed that the continuity of high-frequency keywords gradually changed over time. The current focus of academic research is the formulation and use of relevant consensus.

### **Discussion**

There is no clear conclusion on the biological effects of PCT. The main biological effects are: the role of secondary

inflammatory factors, the role of chemokines, anti-inflammatory and protective effects. But plenty of studies support its use in clinical practice. Previous studies have paid considerable attention to PCT application in areas such as critical care medicine and infectious disease (9,10). This study aimed to analyze the status of PCT-related research in GIM. The search results revealed that 905 documents could be classified in this field, of which only 658 were original articles, and that the number of documents increased sharply after the start of the COVID-19 pandemic in 2020. Our research also found that although China, Turkey, and other countries published many papers, their centrality ranking did not enter the top 5, suggesting that the research is done in these countries mainly involves domestic cooperation and that there is less cooperation with foreign countries. Cooperation is mainly carried out in European countries and the United States. However, analysis of research institutions found that the concentration of cooperation between institutions is relatively low. The author analysis

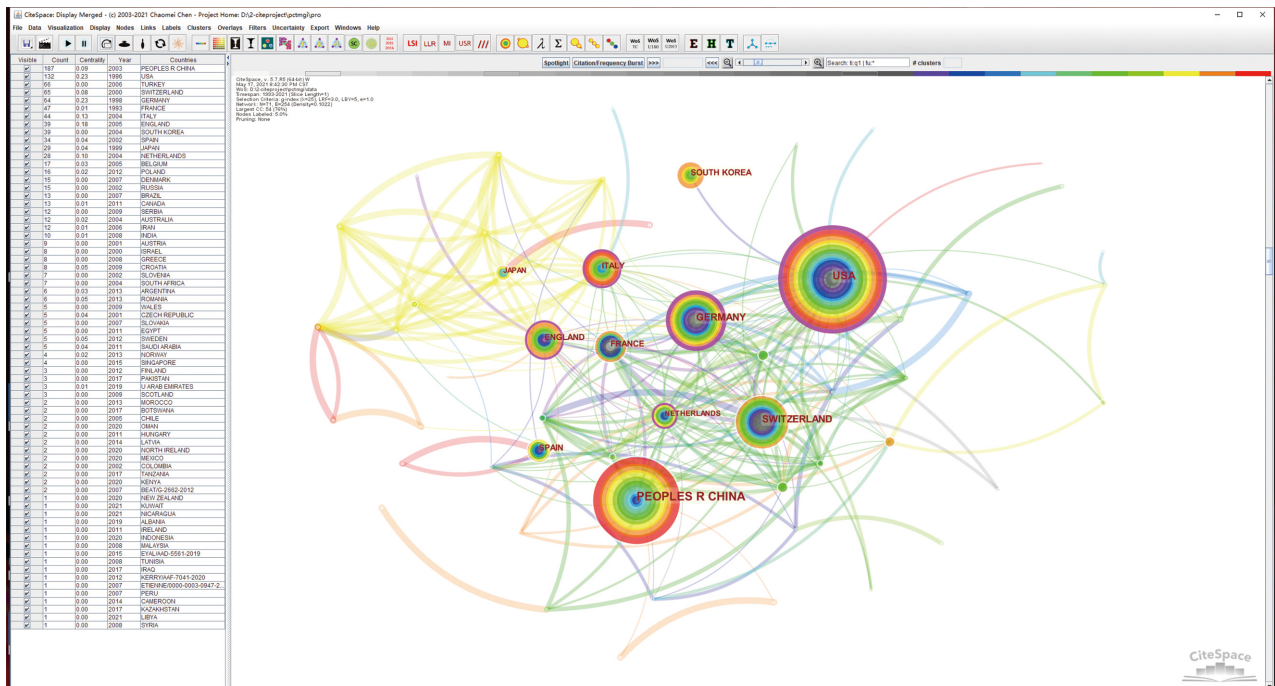


Figure 3 A visual map of countries. There are few national nodes and few contacts.

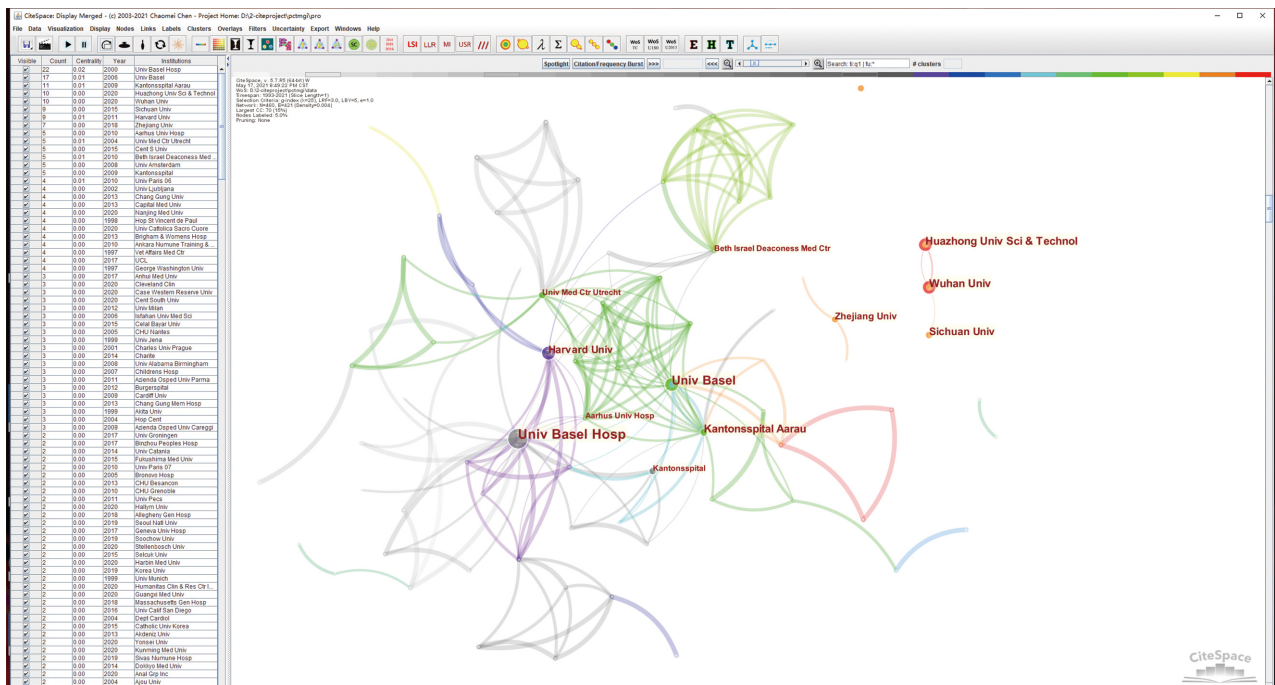


Figure 4 Visual map of organizations. There are few institutional nodes and contacts.

**Table 3** Top 10 countries in terms of publication volume

Rank	Country	Number
1	China	187
2	USA	132
3	Turkey	66
4	Switzerland	65
5	Germany	64
6	France	47
7	Italy	44
8	England	39
9	South Korea	39
10	Spain	34

**Table 4** Top 10 countries for the centrality

Rank	Country	Centrality score
1	USA	0.23
2	Germany	0.23
3	England	0.18
4	Italy	0.13
5	Netherlands	0.10
6	China	0.09
7	Switzerland	0.08
8	Croatia	0.05
9	Romania	0.05
10	Sweden	0.05

showed that leading researchers were essentially from major research institutions, particularly the University of Basel. The journal analysis showed that key research in this area was mainly published in top-tier critical care medicine journals and comprehensive journals, which is a concern. However, keyword analysis results showed that the focus of attention in this field is not significantly different from other fields and is also on infection-related diagnosis, evaluation, and treatment (11-14).

GIM is a discipline that provides primary healthcare

**Table 5** Top 10 institutions by volume of publications

Rank	Institution	Number of publications
1	Univ Basel Hosp	22
2	Univ Basel	17
3	Kantonsspital Aarau	11
4	Huazhong Univ Sci & Technol	10
5	Wuhan Univ	10
6	Sichuan Univ	9
7	Harvard Univ	9
8	Zhejiang Univ	7
9	Aarhus Univ Hosp	5
10	Univ Med Ctr Utrecht	5

**Table 6** Top 7 institutions by the centrality

Rank	Institution	Centrality score
1	Univ Basel Hosp	0.02
2	Univ Basel	0.01
3	Kantonsspital Aarau	0.01
4	Harvard Univ	0.01
5	Univ Med Ctr Utrecht	0.01
6	Beth Israel Deaconess Med Ctr	0.01
7	Univ Paris 06	0.01

**Table 7** Top 9 authors with the most publications

Rank	Author	Number of publications	Centrality score
1	B. Mueller	37	0.01
2	P. Schuetz	24	
3	M. Christ-Crain	10	
4	M. Tamm	6	
5	D. Stolz	5	
6	K.L. Becker	4	
7	D. Gendrel	4	
8	C. Bohuon	4	
9	E.S. Nylen	4	

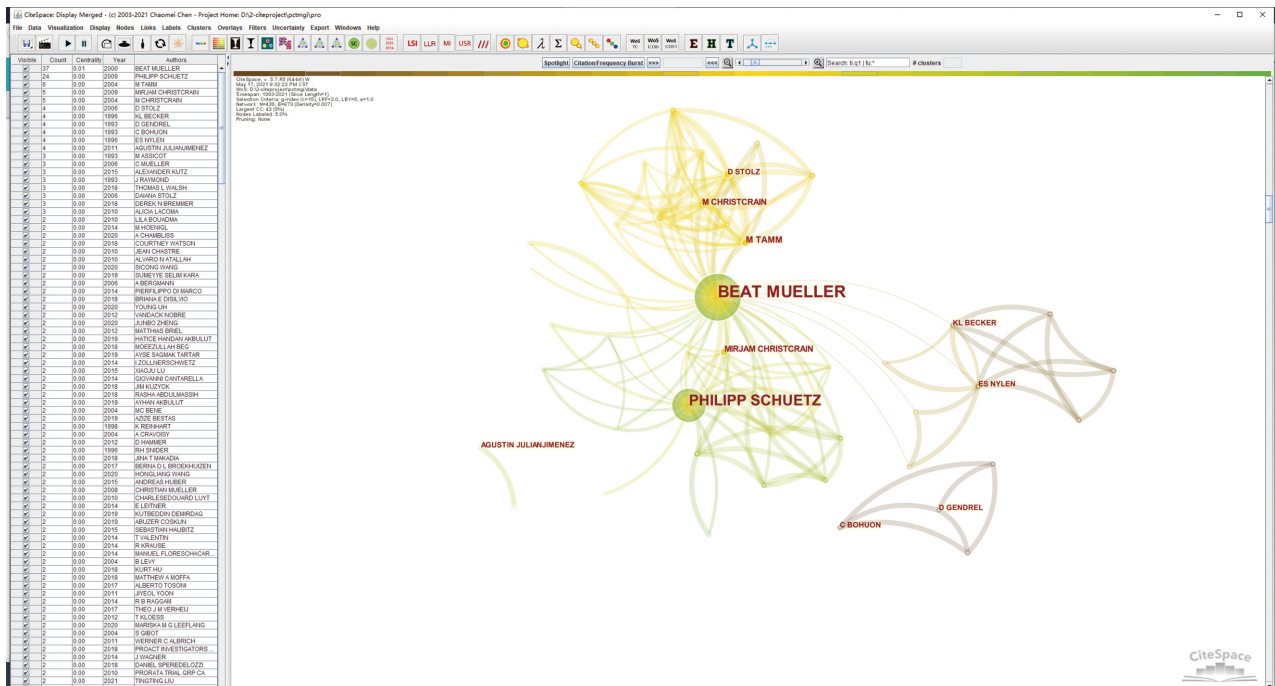


Figure 5 The coauthored visualization map. The authors are scattered and sparsely connected.

Table 8 Top 10 authors by total citations

Rank	Author	Number of citations
1	P. Schuetz	195
2	M. Christ-Crain	142
3	M. Assicot	105
4	M. Meisner	102
5	J.L. Vincent	100
6	B. Muller	86
7	R.C. Bone	77
8	L. Simon	76
9	L. Bouadma	71
10	K.L. Becker	68

Table 9 Top 10 authors by co-cited centrality

Rank	Author	Centrality score
1	M. Assicot	0.21
2	K.L. Becker	0.21
3	R.C. Bone	0.17
4	J.L. Vincent	0.15
5	M. Christ-Crain	0.12
6	F.M. Brunkhorst	0.11
7	M. Meisner	0.09
8	B. Muller	0.08
9	F. Zhou	0.08
10	M.M. Levy	0.07

services on the front line (15). GIM physicians are often their patients' regular physicians and, as such, are responsible for initial diagnosis and treatment services (1). During the COVID-19 pandemic, these doctors have been the fighters at the forefront (16). In the clinical practice of GIM, infections are the most common diagnoses, and relevant research and guidelines on PCT application are

much needed. However, there were very few relevant or targeted studies (17). Our in-depth analysis of the literature showed that most research in this area was on the application of PCT in critically ill patients. The locations of these studies were mostly medical centers, and the patients were most severely ill patients, such as patients with sepsis, severe pneumonia, and COVID-19 infection. The patients

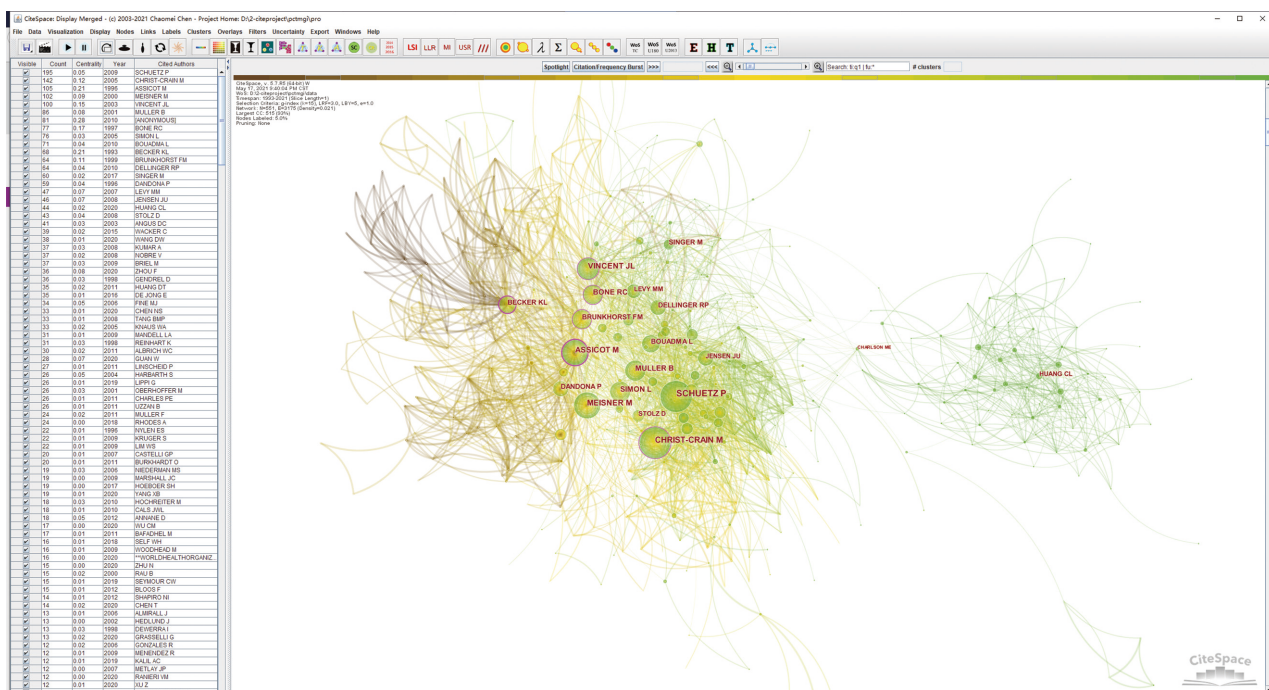


Figure 6 Co-cited author visualization map. The authors have numerous nodes and connections.

Table 10 Journals with more than 20 papers published

Rank	Journal	Number of papers	%
1	Medicine	87	9.6
2	Acta Medica Mediterranea	39	4.3
3	Swiss Medical Weekly	25	2.8
4	BMJ Open	24	2.7
5	Medicina Clinica	24	2.7
6	Journal of Clinical Medicine	23	2.5

Table 11 Top 10 journals by the number of citations

Rank	Journal	Number of citations
1	Crit Care Med	420
2	Lancet	389
3	Clin Infect Dis	352
4	JAMA-J Am Med Assoc	349
5	New Engl J Med	343
6	Intens Care Med	318
7	Crit Care	312
8	Chest	276
9	Am J Resp Crit Care	237
10	PLoS One	178

served by GIM have the following characteristics: various diseases; wide age distribution; many patients with atypical clinical manifestations; and many patients with unknown etiology (4,18). Particularly in patients with fever of unknown origin, it is often necessary to rule out infection immediately (19). It is very important to conduct simple and accurate PCT detection in GIM practice, especially for GIM doctors in small medical institutions, as it is essential to determine the nature of fever as soon as possible (20).

In addition, bedside testing or point-of-care testing is often more conducive to the work of frontline GIM physicians, who can more quickly determine whether a patient's particular index has clinical significance (21). Some

studies that have observed the application value of point-of-care detection of PCT in clinical practice (22,23) have shown that it is unsuitable for distinguishing urinary tract infections or asymptomatic bacteriuria (23). However, other studies have found that in the emergency department, the results of point-of-care detection of whole blood PCT are as accurate as laboratory test results, and PCT can predict 28-day death and bacteremia in patients with suspected



Table 12 Top 10 Journals by the centrality

Rank	Journal	Centrality score
1	Crit Care	0.09
2	Ann Intern Med	0.09
3	Infection	0.09
4	Chest	0.08
5	Clin Chem	0.08
6	Crit Care Med	0.07
7	Arch Intern Med	0.07
8	J Infection	0.07
9	J Clin Endocr Metab	0.07
10	Clin Chim Acta	0.07

infection risk (24). Two studies conducted by Waterfield *et al.* showed that for the diagnosis of suspicious infections in children and young infants, point-of-care detection of PCT also had good accuracy (25,26).

In general, although some studies were classified in the field of GIM, there were relatively few targeted studies, little cooperation between existing studies, and the evidence was weak. Future research should focus more on the application of PCT in GIM to generate more evidence and provide a basis for guiding frontline medical personnel. In conclusion, our present study outlined a birdview of PCT researches in GIM and GIM-related research of PCT should be paid more attention to. There were some limitations in this study. As mentioned above, although the search scope was limited, some of the retrieved documents

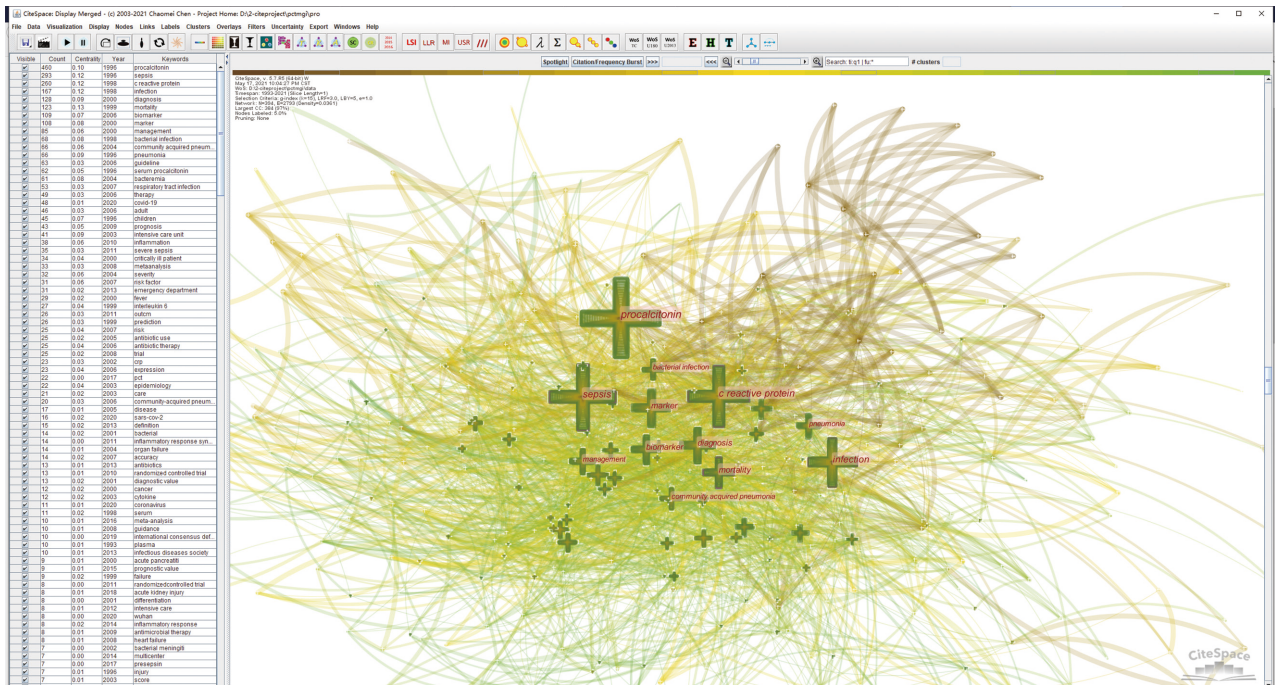


Figure 7 Keyword cooccurrence map. The correlation between keywords is very frequent, and the degree of concentration is high.

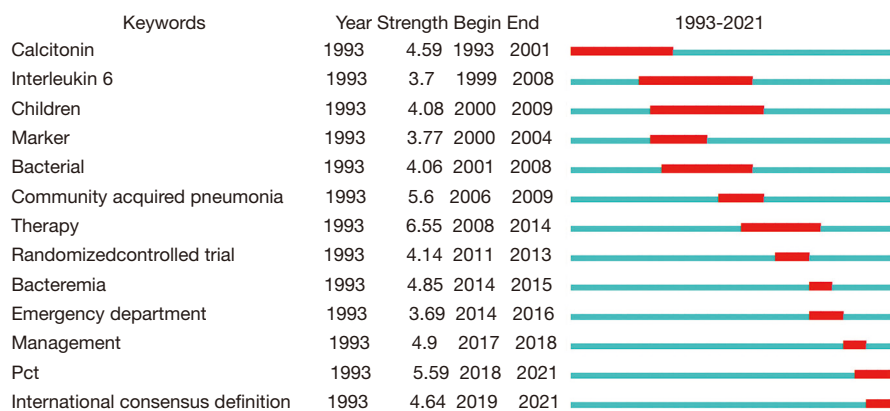
**Table 13** Top 10 keywords used

Rank	Keyword	Number of times keyword used
1	procalcitonin	460
2	sepsis	293
3	c reactive protein	260
4	infection	167
5	diagnosis	128
6	mortality	123
7	biomarker	109
8	marker	108
9	management	85
10	bacterial infection	68

**Table 14** Top 10 keywords by the centrality

Rank	Keyword	Centrality score
1	mortality	0.13
2	sepsis	0.12
3	c reactive protein	0.12
4	infection	0.12
5	procalcitonin	0.10
6	diagnosis	0.09
7	pneumonia	0.09
8	intensive care unit	0.09
9	marker	0.08
10	bacterial infection	0.08

Top 13 Keywords with the Strongest Citation Bursts

**Figure 8** Burst detection shows 13 high-frequency keywords, showing obvious changes over time.

were more focused on intensive care medicine. Of course, there are also critically ill patients in GIM, but relatively speaking, there might have been some biases in the literature selection, which was closely related to document classification.

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## Footnote

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://dx.doi.org/10.21037/apm-21-1689>).

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