Original Article

Report of China's research growth and development in clinical microbiology

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Background: To investigate the academic status of clinical microbiology in China through survey of articles in international clinical microbiology journals and compare the outputs of clinical microbiology research of three major regions in China respectively—Mainland (ML), Taiwan (TW), and Hong Kong (HK).

Methods: All articles of clinical microbiology were selected from "infectious disease", "microbiology" and "virology" categories from Journal Citation Reports (JCR) in Web of Science. Articles from the ML, TW and HK were retrieved from PubMed. The number of total articles, clinical trials, case reports, impact factors (IF) and articles published in each journal were conducted for analyzing.

Results: A total of 13,109 articles from 52 clinical microbiology journals were written by Chinese authors, 8,151 of which are from ML, 3,213 from TW, and 1,745 from HK. And the number of clinical trials and case reports in China is 1,272. Accumulated IF of articles from ML (31,061.1) was much higher than that of TW (11,934.48) and HK (7,301.624), while the average IF of articles from HK is the highest.

Conclusions: The total number of articles from China especially ML increased significantly and steadily in the last decade whereas the amount of articles in HK and TW had been level off. The number of articles published from the ML is dominant through three regions in China, while the quality of articles is best in HK.

Keywords: Clinical microbiology; Chinese authors; literature; survey; journals

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Introduction

Clinical microbiology was just defined by the Union of European Medical Specialties (UEMS) as a specialty in its own right, and was named "medical microbiology". According to the UEMS Section of Medical Microbiology, the main tasks include provision of advice on diagnosis, treatment, and prevention of infection, providing a scientific basis for laboratory diagnosis, undertaking management responsibilities within clinical microbiology laboratories, taking charge of infection control, implementation of antibiotic policy, generation of surveillance data, participation in training of residents and infection-control practitioners, and undertaking of research and development activities in clinical microbiology (1). So, clinical microbiology is very important, especially in the field of offering advice on diagnosis and preventing infectious disease.

With the largest population in the world and as one of the economically fastest booming countries, China is now concerned more about public health which leads to the unsolved problems of clinical microbiology (2). Driven

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by the desire to deepen the understanding of clinical microbiology status in China, we decided to explore the contribution of Chinese scientists in China—the Mainland (ML), Hong Kong (HK) and Taiwan (TW)—to search the published articles in international clinical microbiology journals.

Methods

Journal selection

Journals in the area of clinical microbiology were chosen from categories of "infectious disease", "microbiology" and "virology" of Journal Citation Reports (JCR) in Web of Science. On the one hand, "infectious disease" closely links with "clinical microbiology". On the other hand, "microbiology" referred in the categories includes "parasitology", "mycology" and "bacteriology". Compared with parasitology and mycology, virology is more related to clinic. What's more, mycology, for the most part, belongs to the field of botany. Therefore, we just selected "infectious disease", "microbiology" and "virology" categories in this survey. The journals included in these categories are mostly concerned with the variety of microbiology and virology, some of them are related to veterinary microbiology and virology which should be excluded from the survey. So general medical journals, including *The Lancet*, *The New England Journal of Medicine*, etc.) and comprehensive microbiology and virology journals (such as *Journal of Virology*, *Applied and Environmental Microbiology*) which may partly publish articles about clinical microbiology were excluded from this study (3).

Search strategy and quality assessment

The database PubMed is used for the literature search conducted on computer (which covers over 23 million citations for biomedical literature from Medline, online books, and life science journals) from the origin to March 1, 2017 by two independent reviewers (Y Wang and Y Qi). In order to perform searches in PubMed, the ISSN (Print), first author's affiliation (ML, TW, HK), article types (clinical trials, case reports, and etc.), publication dates were used. China in this article is covering ML, TW and HK. And the accumulated impact factor (IF) and the average IF were derived according to JCR 2015 by the ISI (4).

Results

Journals included

The amount of 52 journals were selected from 197 "infectious disease", "microbiology" and "virology" journals in Web of Science were finally covered in this study. The picking criteria has been mentioned above. As the list shown in *Table 1* (5).

Total numbers of articles and the main trends

A number of 247,935 literatures are published in 52 clinical microbiology journals worldwide, of which 13,109 (13,109/247,935, 5.29%) are contributions from Chinese authors according to first affiliation. There are 8,151 (8,151/13,109, 62.18%) from ML, 3,213 (3,213/13,109, 24.51%) from TW, and 1,745 (1,745/13,109, 13.31%) from HK. In the last decade, the share of Chinese articles has grown (9,123/111,682, 8.17%), the last 5 years (5,611/60,200, 9.32%), and the last 3 years (3,785/37,883, 9.99%). The amount of articles rose significantly since 2007 in China (from 611 to 1,342) and so does in the two main regions (ML: from 334 to 1,090; HK: from 95 to109), but not in TW (from 182 to 143) (6). As the trend presented in *Figure 1*. The share of articles from ML, TW, and HK is as presented in *Figure 2*.

Clinical trials and case reports

Totally there were 33,626 clinical trials and case reports published in 52 journals, among which 1,272 are by Chinese authors (1,272/33,626, 3.78%). There is obviously an upward trend in the proportion of the last 10 years (747/12,775, 5.85%), the last 5 years (410/5,862, 6.99%), the last 3 years (236/3,093, 7.63%). The share of ML is significantly increased, while the same in TW and HK decreased through all years (ML: 608/1,272, 47.80%; TW: 427/1,272, 33.57%; HK: 237/1,272, 18.63%) the last 10 years (ML: 434/747, 58.10%; TW: 211/747, 28.25%; HK: 102/747, 13.65%) last 5 years (ML: 293/410, 71.46%; TW: 69/410, 16.83%; HK: 48/410, 11.71%) last 3 years (ML: 172/236, 72.89%; TW: 35/236, 14.83%; HK: 27/236, 9.44%).

IF

JCR 2015 released that all of the 52 clinical microbiology journals had IF in 2015. All the articles published in the 52

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Table 1 Articles published on 52 clinical microbiology journals

Number	Journal	ISSN	IF [2015]	ML (%)	HK (%)	TW (%)	China (%)	World
1	*J Clin Microbiol*	0095-1137	3.631	671 (53.59)	234 (18.69)	347 (27.72)	1,252 (4.31)	29,075
2	*Clin Infect Dis*	1058-4838	8.736	265 (49.72)	98 (18.39)	170 (31.89)	533 (2.88)	18,517
3	*J Infect Dis*	0022-1899	6.344	343 (55.23)	127 (20.45)	151 (24.32)	621 (2.44)	25,405
4	*Emerg Infect Dis*	1080-6040	6.994	486 (68.26)	103 (14.47)	123 (17.28)	712 (8.58)	8,300
5	*Aids*	0269-9370	4.407	133 (82.10)	13 (8.02)	16 (9.88)	162 (1.28)	12,666
6	*Clin Microbiol Rev*	0893-8512	16.187	15 (51.72)	8 (27.59)	6 (20.69)	29 (2.87)	1,010
7	*Lancet Infect Dis*	1473-3099	21.372	128 (70.33)	34 (18.68)	20 (10.99)	182 (4.58)	3,970
8	*Pediatr Infect Dis J*	0891-3668	2.587	155 (46.27)	40 (11.94)	140 (41.79)	335 (3.18)	10,533
9	*Clin Microbiol Infec*	1198-743X	4.575	156 (54.17)	20 (6.94)	112 (38.89)	288 (5.13)	5,619
10	*Infect Cont Hosp Ep*	0899-823X	3.669	67 (41.88)	26 (16.25)	67 (41.88)	160 (2.68)	5,978
11	*J Med Virol*	0146-6615	1.998	651 (63.02)	105 (10.16)	277 (26.82)	1,033 (13.09)	7,889
12	*Malaria J*	1475-2875	3.079	124 (93.23)	4 (3.01)	5 (3.76)	133 (2.95)	4,515
13	*J Med Microbiol*	0022-2615	2.269	254 (64.63)	58 (14.76)	81 (20.61)	393 (5.39)	7,292
14	*Int J Antimicrob Ag*	0924-8579	4.097	224 (57.29)	34 (8.70)	133 (34.02)	391 (7.91)	4,941
15	*Int J Tuberc Lung D*	1027-3719	2.148	250 (57.74)	81 (18.71)	102 (23.56)	433 (8.06)	5,372
16	*Microbes Infect*	1286-4579	2.291	129 (78.66)	5 (3.05)	30 (18.29)	164 (5.33)	3,075
17	*Epidemiol Infect*	0950-2688	2.515	272 (63.55)	72 (16.82)	84 (19.63)	428 (7.79)	5,492
18	*J Hosp Infect*	0195-6701	2.655	108 (46.55)	70 (30.17)	54 (23.38)	232 (3.61)	6,427
19	*Eur J Clin Microbiol*	0934-9723	2.857	225 (58.90)	40 (10.47)	117 (30.63)	382 (5.75)	6,639
20	*Bmc Infect Dis*	1471-2334	2.69	510 (72.34)	50 (7.09)	145 (20.57)	705 (14.07)	5,009
21	*J Clin Virol*	1386-6532	2.647	235 (67.72)	62 (17.87)	50 (14.41)	347 (9.20)	3,770
22	*Antivir Res*	0166-3542	4.909	370 (75.36)	31 (6.31)	90 (18.33)	491 (13.77)	3,567
23	*Diagn Micr Infec Dis*	0732-8893	2.45	245 (51.47)	66 (13.87)	165 (34.66)	476 (8.53)	5,518
24	*J Infection*	0163-4453	4.382	183 (50.41)	71 (19.56)	109 (30.03)	363 (6.60)	5,497
25	*Sex Transm Infect*	1368-4973	3.015	84 (83.17)	15 (14.85)	2 (1.98)	101 (3.07)	3,289
26	*J Viral Hepatitis*	1352-0504	4.179	234 (70.06)	35 (10.48)	65 (19.46)	334 (13.96)	2,392
27	*Scand J Infect Dis*	0036-5548	1.366	108 (46.35)	29 (12.45)	96 (41.20)	233 (4.10)	5,688
28	*Antivir Ther*	1359-6535	2.916	72 (47.68)	32 (21.19)	47 (31.13)	151 (6.95)	2,174
29	*Int J Infect Dis*	1201-9712	2.229	345 (71.43)	29 (6.00)	109 (22.57)	483 (15.71)	3,075
30	*Int J Med Microbiol*	1438-4221	3.898	29 (76.32)	1 (2.63)	8 (21.05)	38 (2.62)	1,453
31	*Aids Patient Care St*	1087-2914	3.578	65 (79.27)	9 (10.98)	8 (9.76)	82 (2.61)	3,139
32	*Infection*	0300-8126	2.294	51 (38.35)	17 (12.78)	65 (48.87)	133 (2.66)	4,997
33	*Int J Std Aids*	0956-4624	1.3	147 (79.03)	23 (12.37)	16 (8.60)	186 (3.60)	5,162
34	*Tuberculosis*	1472-9792	2.952	108 (93.91)	3 (2.61)	4 (3.48)	115 (8.57)	1,342
35	*Hiv Med*	1464-2662	3.341	14 (53.84)	6 (23.08)	6 (23.08)	26 (1.86)	1,398

Table 1 (*continued*)

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Table 1 (*continued*)

Number	Journal	ISSN	IF [2015]	ML (%)	HK (%)	TW (%)	China (%)	World
36	*Helicobacter*	1083-4389	3.92	87 (60.84)	10 (6.99)	46 (32.17)	143 (9.65)	1,482
37	*Rev Med Virol*	1052-9276	4.308	22 (70.97)	6 (19.35)	3 (9.68)	31 (4.61)	673
38	*Infect Dis Clin N Am*	0891-5520	2.776	5 (83.33)	1 (16.67)	0 (0)	6 (0.56)	1,609
39	*Transpl Infect Dis*	1398-2273	1.459	39 (68.42)	8 (14.04)	10 (17.54)	57 (3.61)	1,578
40	*Microb Drug Resist*	1076-6294	2.529	96 (70.59)	5 (3.68)	35 (25.74)	136 (9.68)	1,405
41	*Jpn J Infect Dis*	1344-6304	1.14	124 (64.92)	5 (2.62)	62 (32.46)	191 (9.56)	1,997
42	*Influenza Other Resp*	1750-2640	2.378	70 (59.32)	42 (35.59)	6 (5.08)	118 (14.25)	828
43	*Curr Hiv Res*	1570-162X	1.562	48 (96.00)	0 (0)	2 (4.00)	50 (5.75)	869
44	*J Infect Dev Countr*	1972-2680	1.139	76 (88.37)	2 (2.33)	8 (9.30)	86 (5.48)	1,570
45	*J Int Aids Soc*	1758-2652	6.256	26 (59.09)	7 (15.91)	11 (25.00)	44 (3.73)	1,180
46	*Med Maladies Infect*	0399-077X	1.422	8 (66.67)	2 (16.66)	2 (16.66)	12 (0.68)	1,772
47	*Hiv Clin Trials*	1528-4336	1.951	4 (100.00)	0 (0)	0 (0)	4 (0.57)	703
48	*Aids Rev*	1139-6121	2.068	6 (66.67)	1 (11.11)	2 (22.22)	9 (2.24)	401
49	*Ann Clin Microb Anti*	1476-0711	2.083	32 (94.12)	1 (2.94)	1 (2.94)	34 (6.92)	491
50	*Aids Res Ther*	1742-6405	1.414	16 (88.89)	2 (11.11)	0 (0)	18 (4.25)	424
51	*Mol Oral Microbiol*	2041-1006	3.061	10 (71.43)	2 (14.29)	2 (14.29)	14 (4.93)	284
52	*Pathog Dis*	2049-632X	2.483	26 (89.66)	0 (0)	3 (10.34)	29 (5.99)	484

% in ML (TW, or HK) category is the proportion of articles published in Mainland (Taiwan, or Hong Kong) compared with Greater China; % in China category is the proportion of articles published in Greater China compared with the world. IF, impact factor; ML, Mainland; TW, Taiwan; HK, Hong Kong.

journals has the accumulated and average IF of 50,297.21 and 3.837. It is not a surprise that the accumulated IF number of articles from ML (31,061.1) was far larger than that of TW (11,934.48) and HK (7,301.624), and the average IF number of articles from HK is the largest (ML: 3.811, TW: 3.714, HK: 4.184).

Admittedly, keeping the average IF in the pretty high level with the large amount of accumulated IF, the ML of China has been making progress considerably in the study of clinical microbiology. The trend of the accumulated IF of articles from China is as presented in *Figure 1B*,*C*.

Articles published on clinical microbiology journals

The top-ranking clinical microbiology journal is *The Lancet Infectious Diseases* (IF 21.372) which has great reputation in the field of clinical microbiology both in China and the other countries and districts in the world. China has a possession for 4.58% (182/3,970). ML published 128 articles on *The Lancet Infectious diseases* while it contains 20 and 34 articles from TW and HK correspondingly.

Among Chinese authors, the most popular journals are *the Journal of Clinical Microbiology* (with largest number of articles: 1,252) and *International Journal of Infectious Diseases* (*IJID*) (with largest percentage of articles: 15.71%). Comparatively, *the Journal of Clinical Microbiology* is most popular in TW and HK too, with the most published articles. The distribution of articles published in the 52 radiation oncology journals was presented in *Table 1*.

Discussion

As far as we know, this report is the first one that reveals the contribution of authors in China including ML, TW, and HK to the research in international clinical microbiology journals. We found that China has improved the research in clinical microbiology area in this century gradually, especially ML. As the articles published in major

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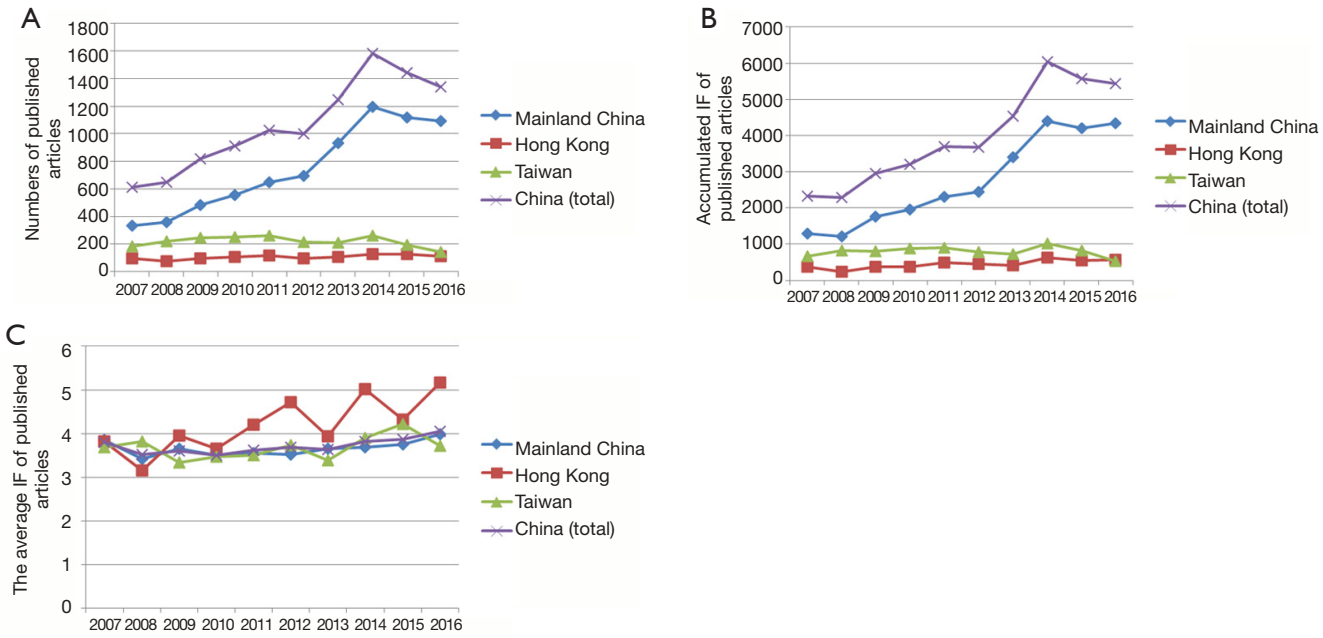

Figure 1 The trend of the number of articles from China, 2007–2016. (A) The trend of the number of articles from China (total), Mainland, Taiwan, and Hong Kong, 2007–2016; (B) the trend of the accumulated IF of articles from China (total), Mainland, Taiwan, and Hong Kong, 2007–2016; (C) the trend of the average IF of articles from China (total), Mainland, Taiwan, and Hong Kong, 2007–2016.

international clinical microbiology journals has increased in the last ten years, we are now witnessing rapid development of China in this field (7).

China's economy has grown remarkably. Based on the statistics of GDP, China has become the 2nd largest economy in the world, inferior to the USA (6). Issues about population aging, deficient exercise, tobacco and alcohol abuse, worsen environmental, food safety etc. draws attention socially as well as medically. One of the biggest issues that is concerned with public health is the overuse of antibiotics (8,9). It is reported that in 2013, China used about 160,000 tons of antibiotics, which accounted for half of the use in the whole word. The 52% of those used for livestock and 48% used for human infection. Plus, over 50,000 tons of antibiotics was discharged into water-soil environment. With regard to the average use of antibiotics in patients, China outnumbered 5 times much more than western countries which leads to the occurrence of some Super bacteria and multidrug-resistant organism (MDRO), such as MRSA, VRE, ESBL etc. (10). The Chinese government has recognized the importance of clinical microbiology research in resolving problems like this, which is, to some degree, promoting the development of clinical medicine (11,12).

And the outbreak of unprecedented infections in China caused by new type of microorganism, like SARS, H5N1 and H7N9 influenza, happened in last 15 years, which is also a contributing factor to push the progress made in clinical microbiology field (13). The development of clinical microbiology relies heavily upon the laboratory medicine. Therefore, the learning and working situation of laboratory professionals can reflect the development of clinical microbiology. According to Chen's survey (14), the frequency of retrieving articles in Italy is nearly 1.9 times over China. In Chen's survey, the difference between Italy and China can partly explain the gap between China and developed countries in clinical microbiology. China can improve clinical microbiology by training laboratory professionals in a suitable way.

The articles in this research were retrieved with the computer-generated search from MEDILINE and JCR. Both are recognized database, containing high-quality scientific literatures and most influential biomedical journals. It is worth mentioning that although IF is not the optimal parameter to determine the quality of articles, for the high-IF journals may sometimes publish poor-quality articles. However, it is still the best available parameter to determine the quality of studies by far.

In this research, we assessed the clinical microbiology

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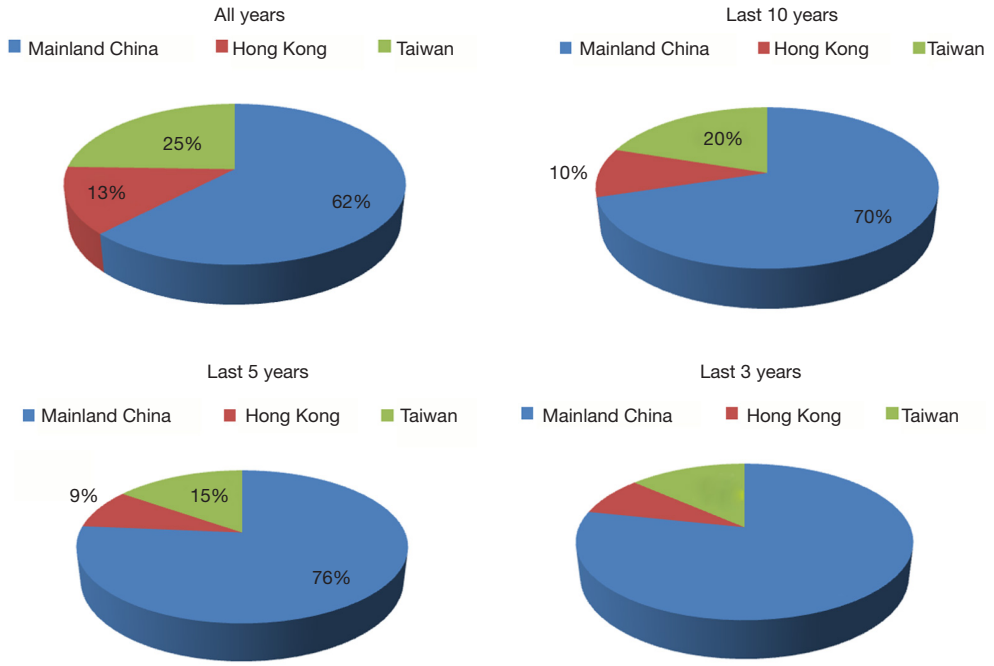

Figure 2 The proportion of articles from Mainland, Taiwan, and Hong Kong in all years, the last 10, 5 and 3 years.

development in China from the perspective of published literatures and made comparison between the three main regions. The total numbers as well as the proportion of the articles published in clinical microbiology journals presented a significant increase in the last decade. The amount of published articles from ML is dominant through three regions since IF and articles published in top clinical microbiology journals were used for quality comparisons, and the gap of clinical microbiology research articles among ML, TW and HK still appears to be very huge. HK had the highest average IF of 4.279, and the second one if ML of 3.826, TW of 3.822. HK and TW have been at the forefront for many years of scientific and medical research, but from our study, we can see that ML even outrun TW in terms of average IF number. With the largest amount of articles number and second highest IF number in three regions, it is a great signal for the clinical microbiology research in ML (15).

The share of clinical trials from ML has increased in the last decade while that of TW and HK have both decreased. There are many reasons to explain this phenomenon: firstly, ML has put more emphasis on high-quality clinical investigation these years and the contribution is growing significantly. Secondly, ML has a very large population of 1.4 billion and clinical trials conducted in ML cost much less and more convenience.

There must be limitations in any study, and this one is no exception. Though the journals were selected from "infectious disease", "microbiology" and "virology" category from Web of Science, a few journals may deal with issues beyond clinical microbiology, and there may be some articles in comprehensive microbiology journals, general medicine journals, and other kinds of medical journals not covered in this study. We limited the author's affiliation by (China, HK or TW), and those only addressed particular cities or provinces have been neglected. In fact, Macau was included in our previous design, but it was excluded later when we found there were few articles affiliated to it. Only three regions included in our study, it still can reflect the status of the research on clinical microbiology in the whole China (16).

Conclusions

The amount of articles published in clinical microbiology journals from ML of China increased significantly during the last 10 years, whereas the articles published by researchers from HK and TW stabilized. The quality of articles from HK is the best, though the number of articles published from the ML has exceeded those from TW and HK. In general, the contribution by Chinese authors in clinical microbiology has been growing promisingly.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jlpm.2017.06.16). Bing Gu serves as an unpaid Executive Editor of *Journal of Laboratory and Precision Medicine* from November 2016 to October 2021. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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