



# Analysis of the Competitiveness of Science and Technology Innovation of Hospitals in Yangtze River Delta Region, China

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**Abstract. Objective** This paper aims to analyze the competitiveness of science and technology innovation in hospitals within the Yangtze River Delta region and to provide references for the construction and development of medical disciplines and hospitals in this region. **Methods** To analyze the science and technology innovation development of the top 100 hospitals and disciplines in the Yangtze River Delta region, we utilized one-way ANOVA and the rank-sum ratio (RSR) comprehensive evaluation method based on the Science and Technology Evaluation Metrics (STEM) from 2018 to 2022. **Results** There are significant geographical differences in the quantitative values of science and technology innovation among hospitals in the Yangtze River Delta region, with Shanghai exhibiting the strongest performance. The distribution of attributions among the top 100 disciplines is uneven, as more than 60% of hospitals are affiliated with universities. The four areas (Shanghai, Zhejiang, Jiangsu and Anhui) within the Yangtze River Delta region display varying strengths and weaknesses across different disciplines. **Conclusions** We strongly recommend that the Yangtze River Delta region strengthen institutional cooperation and enhance multidisciplinary cross-fertilization to improve overall competitiveness in science and technology innovation.

**Keywords:** Science and technology evaluation metrics, Regional comparison, Rank-sum ratio comprehensive evaluation method, Yangtze River Delta.

## 1 Introduction

In 2018, the Yangtze River Delta Region Integration Plan was elevated as a national strategy in China[1]. Encompassing the provinces of Zhejiang, Shanghai, Jiangsu and

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Anhui, the Yangtze River Delta (YRD) region accounts for one-third of China's research and development (R&D) expenditures and effective invention patents[2,3]. Scientific and technology (S&T) developments heavily depend on the medical health sector, with hospitals being a crucial component of health innovations and the growth of regional health industries[4]. Although there are extensive collaborations among hospitals in the YRD region, such as specialty alliances and academic conferences[5], a unified cooperation and comprehensive description encompassing all hospitals in the region are still missing.

This paper investigates the development and diversity of hospitals and medical disciplines in the YRD region that ranked among the top 100 in China (hereinafter referred to as "Top 100 hospitals" and "Top 100 disciplines"). By analyzing the Science and Technology Evaluation Metrics (STEM), we aim to provide a valuable reference for the future cooperation development among hospitals in the YRD region. This paper highlights the characteristics of hospitals and medical disciplines in Zhejiang, Shanghai, Jiangsu and Anhui, and offers insights into their strengths and areas for improvement.

## 2 Data and Methodology

The Science and Technology Evaluation Metrics (STEM) for China's Medical Colleges and Hospitals, which rank the top 100 hospitals by overall performance and by specific disciplines from 2018 to 2022 were downloaded from the official website (<http://top100.imicams.ac.cn/home>). The evaluation indexes include S&T output, academic influence, and technological condition.

The Chinese Academy of Medical Sciences identifies 31 independent disciplines from 2019 (there are 29 disciplines in 2018) and categorizes them into three general groups: internal medicine, surgery, and other specialties. For the purpose of this study, we expanded the categories by extracting nursing and oncology as independent categories, considering oncology's involvement in both internal medicine and surgery, and the growing significance of nursing in recent years. Consequently, we classified all disciplines into five main categories: internal medicine, surgery, specialties, nursing and oncology. The detailed classification is shown in Table 1.

**Table 1.** Major medical categories and disciplines

Categories	Disciplines
Internal Medicine	Allergology, Epidemiology, Rheumatology, Autoimmunity, Respiratory Diseases, Tuberculosis, Psychiatry, Endocrinology and Metabolic Diseases, Neurology, Nephrology, Gastroenterology, Cardiovascular Diseases, Hematology.
Surgery	Orthopedic Surgery, Emergency Medicine, Anesthesiology, Urology, General Surgery, Bum Surgery, Neurosurgery, Cardiovascular Surgery, Thoracic Surgery, Plastic Surgery, Critical Care Medicine.
Specialties	Pediatrics, Otolaryngology, Obstetrics & Gynecology, Dentistry, Dermatology, Ophthalmology.
Nursing	Nursing.
Oncology	Oncology.

Excel was used to generate statistical descriptions of the distributions of the top 100 hospitals and disciplines in the YRD region. One-way ANOVA and multiple comparison analysis were conducted to examine regional differences among the top 100 hospitals and the top 100 disciplines. More specific, the Levene test was applied for variance homogeneity test in the one-way ANOVA, and the Tukey test was used for the multiple comparisons. A P-value of 0.05 or less was considered statistically significant.

To identify the strength of disciplines in each province or city, the rank-sum-ratio (also known as RSR) method was employed based on the number of top 100 disciplines and the total score of each discipline[6]. The one-way ANOVA, multiple comparison analysis and RSR were performed by R 4.2.0.

### 3 Results

#### 3.1 Top 100 Hospitals

Between 2018 and 2022, an average of 32 hospitals in the YRD region were ranked among the 'Top 100 Hospital' (32 in 2018, 33 in 2019, 31 in 2020, 31 in 2021, and 33 in 2022). Additionally, the YRD region has a significantly higher proportion of top 100 hospitals to tertiary hospitals compared to the national level ( $P=0.000006825$ ). All related results are displayed in Table 2.

**Table 2.** Top 100 hospitals from 2018 to 2022 in YRD region

Area	No.Tertiary Hospitals	2018(accounts for tertiary hospitals %)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
Shanghai	33	18(54.54%)	19(57.57%)	15(45.45%)	17 (51.52)	17 (51.52)
Zhejiang	51	7(13.72%)	7(13.72%)	9(17.64%)	7 (13.72)	9 (17.65)
Jiangsu	53	6(11.32%)	6(11.32%)	6(11.32%)	5 (9.43)	5 (9.43)
Anhui	22	1(4.54%)	1(4.54%)	1(4.54%)	2 (9.09)	2 (9.09)
YRD Region	159	32(20.12%)	33(20.75%)	31(19.50%)	31 (19.50)	33 (20.75)
Nationwide	1130	100(8.84%)	100(8.84%)	100(8.84%)	100 (8.84%)	100 (8.84%)

Shanghai has the highest number of top 100 hospitals, followed by Zhejiang. Additionally, the proportion of top 100 hospitals to local tertiary hospitals is significantly higher in Shanghai compared to the other three provinces. The proportion of the top 100 hospitals in Zhejiang is also significantly higher than that in Anhui. There is no significant difference between Jiangsu and Zhejiang and between Jiangsu and Anhui. The multiple comparisons results can be found in Table 3.

**Table 3.** Multiple comparison of the percentage of top 100 hospitals from 2018 to 2022

Area A	Area B	Difference in the mean	P-value	95% Confidence Interval	
				Lower	Upper
Zhejiang	Shanghai	-0.3683	0.0000	-0.4196	-0.3170
Zhejiang	Jiangsu	0.0473	0.0762	-0.0040	0.0985
Zhejiang	Anhui	0.0893	0.0007	0.0380	0.1406
Shanghai	Jiangsu	0.4156	0.0000	0.3643	0.4668
Shanghai	Anhui	0.4576	0.0000	0.4063	0.5089
Jiangsu	Anhui	0.0420	0.1287	-0.0092	0.0933

### 3.2 Top 100 Disciplines

There were more than 900 disciplines in the YRD region ranked among top 100 disciplines since 2019. The number of top 100 disciplines in YRD region by areas was shown in Table 4. The total number of top 100 disciplines increased from 2018 to 2022. Shanghai has the highest number of top 100 disciplines for five consecutive years, accounting for more than 40% of the total in the YRD region, followed by Jiangsu.

**Table 4.** Number of top 100 disciplines in YRD region (by area)

Area	2018(accounts for total disciplines%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
Shanghai	386 (45.68)	376 (41.78)	366 (40.67)	366 (39.65)	364(39.22)
Zhejiang	171(20.24)	212 (23.56)	215 (23.89)	221 (23.95)	221(23.81)
Jiangsu	232(27.46)	242 (26.89)	251(27.89)	260 (28.17)	262(28.24)
Anhui	56(6.63)	70(7.78)	68(7.56)	76 (8.23)	81 (8.73)
Total	845(100)	900(100)	900(100)	923 (100)	928 (100)

There are significant differences between each province and city in the percentage of top 100 disciplines. The results of multiple comparisons are shown in Table 5.

**Table 5.** Multiple comparison of the number of top 100 disciplines from 2018 to 2022

Area A	Area B	Difference in the mean	P-value	95% Confidence Interval	
				Lower	Upper
Zhejiang	Shanghai	-0.1831	0.0000	-0.2120	-0.1542
Zhejiang	Jiangsu	-0.0464	0.0015	-0.0753	-0.0175
Zhejiang	Anhui	0.1530	0.0000	0.1242	0.1819
Shanghai	Jiangsu	0.1367	0.0000	0.1078	0.1656
Shanghai	Anhui	0.3361	0.0000	0.3073	0.3650
Jiangsu	Anhui	0.1994	0.0000	0.1706	0.2283

The number of top 100 disciplines in the YRD region by university affiliated and non-university affiliated hospitals are shown in Table 6. More than 60% of the top 100

disciplines in the YRD region are university-affiliated hospitals, while less than 40% are non-university-affiliated hospitals.

**Table 6.** Number of top 100 disciplines in YRD region (by attribute)

Area	2018(ac- counts for to- tal disci- plines %)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
Non-university affli- ated	321(37.99)	357 (39.67)	341(37.89)	304(32.94)	302 (32.54)
University affiliated	524(62.01)	543(60.33)	559(62.11)	619 (67.06)	626 (67.46)
<b>Total</b>	845(100)	900(100)	900(100)	923 (100)	928 (100)

We selected data from the year 2019 and 2020 for the rank-sum-ratio analysis, as critical care medicine and anesthesiology were first included in 2019. We classified the disciplines into three categories: strong disciplines, intermediate disciplines and inferior disciplines, using two-dimensional data of the number and total score of top 100 discipline. The formulae we obtained were:

$$\text{YRD region: } y = -0.637 + 0.21 * \text{Probit};$$

$$\text{Shanghai: } y = -0.625 + 0.2 * \text{Probit};$$

$$\text{Zhejiang: } y = -0.576 + 0.189 * \text{Probit};$$

$$\text{Jiangsu: } y = -0.705 + 0.223 * \text{Probit};$$

$$\text{Anhui: } y = -0.485 + 0.158 * \text{Probit}.$$

The classification of strong and inferior disciplines is shown in Table 7.

**Table 7.** Classification disciplines of top 100 disciplines in the YRD region

Area	Strong disciplines	Inferior disciplines
YRD region	Oncology, plastic surgery, obstetrics and gynecology, respiratory medicine, neurosurgery.	Infectious diseases, stomatology, tuberculosis, otolaryngology.
Shanghai	Endocrinology and metabolic diseases, oncology, respiratory medicine, emergency medicine, cardiovascular medicine.	Burn surgery, stomatology, psychiatry, tuberculosis.
Zhejiang	Critical care medicine, plastic surgery, respiratory medicine, psychiatry, anesthesiology.	Stomatology, tuberculosis, cardiovascular surgery, otolaryngology.
Jiangsu	Plastic surgery, hematology, cardiovascular surgery, nursing, neurology.	Dermatology, infectious diseases, stomatology, otolaryngology.
Anhui	Dermatology, plastic surgery, rheumatology and autoimmunity, obstetrics and gynecology, anesthesiology.	Tuberculosis, cardiovascular disease, orthopedics, pediatrics.

## **4 Conclusions**

### **4.1 Strengthen Cooperation between Colleges and Universities and Enhance Cross-Disciplinary Integration**

Our findings reveal that the proportion of top 100 hospitals to tertiary hospitals in the Yangtze River Delta region (YRD) region is significantly higher than the national average between 2018 and 2022. However, there are regional differences within the YRD region. Shanghai, equipped with the robust economy and advanced higher education system[7], has the highest number and proportion of top 100 hospitals in the YRD region.

University-affiliated hospitals exhibit higher quantitative values of scientific and technological innovation, largely due to their teaching and research advantages in major disciplines[8,9]. To sustain and enhance this progress, it is recommended to leverage the strengths of regional higher education institutions to foster the development of local disciplines. This includes actively promoting interdisciplinary cross-fertilization and innovative development within institutions, encouraging the cultivation of multidisciplinary medical talents, and using colleges and universities as a bridge to drive scientific and technological innovation in hospitals[10].

### **4.2 Complementary Strengths and Achieve Differentiated Regional Diversification**

The rank-sum ratio (RSR) comprehensive evaluation method considers both the quantity and quality of the top 100 disciplines, identifying those with a high number of top rankings and relatively high scores as strong disciplines in the area. In the YRD region, the strong disciplines include oncology, plastic surgery, obstetrics and gynecology, respiratory disease, and neurosurgery. Additionally, Shanghai, Zhejiang, Jiangsu and Anhui each have their own strong disciplines. We recommend that these regions continue to accelerate the development of their advantageous disciplines to form distinctive regional characteristics.

For the inferior disciplines, it is advisable to seek medical resources within the YRD region and to collaborate with more advanced regions[11]. For example, cardiovascular pathology is a weaker discipline in Anhui but a strong one in Shanghai. Strengthening exchanges and cooperation between these regions can comprehensively enhance the scientific and technological innovation capabilities of hospitals throughout the YRD region.

By leveraging the unique strengths of each province and city, and promoting the exchange of medical resources and expertise, the YRD region can achieve more balanced and robust growth in healthcare innovation [12]. These insights provide valuable references for policymakers and healthcare administrators to strategize the future development of medical disciplines and enhance the overall competitiveness of hospitals in the region.

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