Breast ultrasound in Chinese hospitals: A cross-sectional study of the current status and influencing factors of BI-RADS utilization and diagnostic accuracy

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Summary

Background With the growing demand for breast screening in public health services and clinical care, ultrasound departments in China are facing tremendous challenges.

Methods A cross-sectional nationwide survey was conducted in 5,460 departments providing ultrasound diagnoses in mainland China from 2020 to 2021. The survey included general information about the ultrasound department, the characteristics of sonologists, the use of Breast Imaging Reporting and Data System (BI-RADS) templates, and the diagnostic accuracy rate of breast cancer ultrasound.

Findings There were on average 2.25 sonologists per 10,000 patients in mainland China per year. The average utilization rate of BI-RADS in Chinese hospitals was 87.02%. The GDP per capita of the province (P = 0.008), whether the hospital was specialized (P = 0.002) or a Tier 3 facility (P < 0.001), the percentage of doctors with master’s and doctoral degrees (P < 0.001) and doctors ≤ 35 years (P = 0.005) were significantly and independently associated with the utilization rate of BI-RADS. The average diagnostic accuracy rate of breast cancer ultrasound in Chinese hospitals was 73.64%, and we observed significant positive associations between GDP per capita (P = 0.02), BI-RADS utilization rate (P = 0.019), and breast cancer ultrasound diagnostic accuracy.

Interpretation The utilization of BI-RADS templates effectively improved the diagnostic accuracy of ultrasound. Moreover, the survey summarized the current situation of departments and sonologists providing breast ultrasound diagnosis in mainland China, which helped monitor the development of the discipline and provide information for administrators to meet the growing demand.

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Keywords: Ultrasound; Breast cancer; Breast imaging reporting and data system (BI-RADS)

Introduction

Breast nodules are a very common medical problem among women in China. The incidence of breast cancer has risen dramatically over the past two decades.1 Detecting breast nodules and accurately diagnosing cancer are the goals of various imaging modalities. The diagnostic accuracy of both physical examination and mammography is low in Chinese women due to denser breast tissue.2-3 Ultrasound can assess breast nodules both in predominantly fatty breasts and in dense glandular structures4 and is also the ideal imaging tool to guide subsequent procedures, further enhancing its utility in breast cancer diagnosis.5-7

In 2003, the first edition of the Breast Imaging Reporting and Data System (BI-RADS) lexicon of the American College of Radiology (ACR) was created to standardize ultrasound templates and improve

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communication among healthcare providers. Based on suspicious ultrasound features, the fifth edition of BI-RADS, which outlines the risk stratification and standardized management strategies of breast lesions, has been widely used.

With the growing demand for breast screening in public health services and clinical care for one-fifth of the world’s population, ultrasound departments in China are facing tremendous challenges. By searching the literature, we identified no studies that investigated the current status of breast ultrasound in China and the factors affecting the use of BI-RADS templates and accuracy of breast cancer ultrasound diagnosis.

Methods

This study was approved by the ethics committee of the principal investigator’s hospital and is registered at ClinicalTrials.gov (ChiCTR1900023916). All procedures performed in the studies were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Study design and population

At the request of the National Ultrasound Quality Control Center (NUQCC), which is the official institution to standardize the quality control of ultrasound medicine in China. A national survey collaboration network was established for this study. The cross-sectional survey was conducted between July 1, 2020, and July 1, 2021. With the help of local governments and health commissions, Tier 2/3 hospitals in mainland China were invited to participate in the survey. The investigation is a non-mandatory questionnaire. Finally, a total of 5460 departments providing ultrasound diagnosis in mainland China were voluntarily enrolled, including 11 provinces, autonomous regions, and municipalities. The number of Tier 3 hospitals and Tier 2 hospitals in mainland China in 2021 was 2996 and 10,404, respectively, according to data from the National Health Commission of China. The overall sample size of the survey reached 40.7% of the total number of 2/3 hospitals in mainland China.

Survey indicator design

The indicators were discussed before the survey. Ten panel experts, including 6 ultrasound experts (3 of whom had administrative roles), 1 experienced medical quality manager, 1 researcher, 1 medical service department personnel and 1 policy-maker, were selected from the working committee of NUQCC for questionnaire development and they were independent from the hospitals enrolled. To propose the indicators, the panel experts were asked to propose the indicators based on current practice patterns, knowledge, and from structure, process, and result quality control levels. To modify the indicators, all 82 experts at the NUQCC and management specialists were encouraged to submit written opinions on adding, deleting or merging indicators. To determine the indicators, the aggregated results of written opinions were presented to the panel experts. Again, the panel experts were asked to evaluate the significance and feasibility of the recommendations and to determine the final indicators.

All the detailed information on the website was structured into 22 indicators, including (1) general information of the hospitals, such as the hospital tier, hospitals ownership and category, hospital location, and quality inspection rate of ultrasonic instruments; (2) information about the departments’ sonologists, such as their age, ranking, and education; (3) workload of the department, such as the average sonologists per 10,000 patients per year; and (4) the use rate of BI-RADS templates and the accuracy rate of breast cancer ultrasound diagnosis in the department.
Definitions of the survey indicators
The ownership of hospitals in mainland China is divided into state-owned hospitals and private hospitals. Public hospitals are generally referred to as non-profit hospitals run by the state, and private hospitals are referred to joint-stock hospitals run by individuals or partners, which are for-profit hospitals. Chinese hospitals in mainland China are classified into Tiers 1, 2, and 3. The standards of hospital grading mainly include hospital scale, management level and medical quality of the hospitals, such as diagnosis quality, treatment quality, and nursing quality. The higher the tier, the better the hospital. There are also general hospitals and specialized hospitals. Specialized hospitals refer to hospitals that specialize in a certain disease, while general hospitals are hospitals that are engaged in multiple types of diseases. There are various specialties, such as internal medicine, surgery, obstetrics and gynaecology, and paediatrics. Physician rankings in mainland China include chief, associate chief, attending and resident physicians, which are different from the rankings used in Europe and the United States. The upgrading of a physician’s ranking is based on educational background, clinical hours, practice level, and academic achievement.

The average number of sonologists per 10,000 patients refers to the number of sonologists required to complete each 10,000 ultrasound examinations in one year. The ultrasound instrument quality inspection rate was defined as the number of ultrasound instruments passing the quality inspections to the total number of ultrasound instruments in the ultrasound department during the same period. The quality inspection of the ultrasound instrument was carried out by the nationally recognized metrology and testing agency, and a qualified mark was issued.

The BI-RADS utilization rate is defined as the proportion of ultrasound reports of breast lesions classified by ACR BI-RADS Ultrasound 2013 to the total number of breast reports during the same period. Each participating hospital randomly selected no fewer than 100 breast ultrasound reports and calculated the utilization rate of BI-RADS templates.

The breast cancer ultrasound diagnosis accuracy rate is defined as (true positive cases + true negative cases)/ the total number of cases during the same period. No fewer than 100 cases diagnosed by breast ultrasound and confirmed by pathology were randomly selected from each participating hospital. True positives and true negatives refer to ACR BI-RADS Ultrasound 2013. True positives on breast cancer ultrasound are cases with a breast ultrasound diagnosis of BI-RADS Category 4/5 and biopsy or surgical excision with confirmed malignant pathology. True negatives of breast cancer ultrasound are cases with a breast ultrasound diagnosis of BI-RADS Category 1/2/3 and biopsy or surgical excision with confirmed benign pathology. The final pathologic results were considered the gold standard for diagnosis.

According to the National Bureau of Statistics of China, the economic development level of the 31 provinces is measured by per capita gross domestic product (GDP). GDP per capita is divided into two categories: high and low. Beijing, Shanghai, Jiangsu, Fujian, Zhejiang, Guangdong, Tianjin, Chongqing, Hubei, Shandong, Inner Mongolia, Shaanxi, Anhui, Hunan, Hainan, and Sichuan are regions with a high GDP. Those with low levels of economic development include Liaoning, Henan, Ningxia, Jiangxi, Xinjiang, Tibet, Yunnan, Qinghai, Guizhou, Hebei, Shanxi, Jilin, Guangxi, Heilongjiang, and Gansu (http://www.stats.gov.cn/).

Investigative procedures
Each hospital completed the real-name registration on the website. The survey was completed electronically on the website after approval. The interviewers were designated persons in the ultrasound departments (usually administrative secretaries). All interviewers were trained for one day prior to the survey to familiarize with the indicators and improve their investigative skills. The survey was conducted in face-to-face interviews with the respondents (chief or a designated person from the department). Data entry was uploaded synchronously by the interviewers. The rationality and logicality of each hospital’s data were evaluated by data specialists. If unqualified results were found, the data was sent back to the department for re-survey and acquisition. Final data quality control was performed by the survey committee.

Statistical analysis
Categorical variables are presented as frequencies and were analysed using the chi-squared test. Quantitative data are expressed as the mean ± standard deviation (SD). For continuous data, an unpaired t test was used to assess the differences between the two groups. Based on the parameter estimates from the statistically significant results of the t tests, a multivariate logistic regression model was established to evaluate the correlations between the factors and breast cancer ultrasound diagnostic accuracy rate. We used a linear mixed model to estimate the BI-RADS utilization rate. All statistical analyses were performed using SPSS software version 19.0 (IBM, Armonk, NY, USA). Differences at P<0.05 were considered statistically significant.

Role of the funding source
The funders played no role in the study design, collection or analysis of data, interpretation of results, or writing of the report.
## Results

### Departments providing ultrasound diagnosis in mainland China

A total of 5,460 departments providing ultrasound diagnoses in mainland China were enrolled. Thirty-one provinces of mainland China participated. The number of hospitals from each province is shown in [Figure 1](#fig1).

There were 4,749 (87.00%) and 711 (13.00%) departments belonging to state-owned hospitals and private hospitals, respectively. Among all the departments, 1,869 (34.23%) were in Tier 3 hospitals, while 3,591 (65.77%) were in Tier 2 hospitals. Regions with a higher GDP per capita level had a significantly higher percentage of Tier 3 hospitals (38.31% vs. 29.11%, *P* < 0.001). A total of 4,424 (81.00%) departments were found in general hospitals, and 1,036 (19.00%) departments were located in specialized hospitals. All departments’ organizational characteristics were analysed and are presented in Supplemental Table 1.

### The general characteristics of sonologists in mainland China

There were on average 2.25 sonologists per 10,000 patients per year in mainland China ([Figure 2](#fig2)). Regions with a lower GDP per capita level had a significantly higher number of sonologists per 10,000 patients than regions with a higher GDP per capita (2.36 vs. 2.14, *P* < 0.001). The sonologists per 10,000 patients differed considerably between Tier 3 and Tier 2 hospitals (1.68 vs. 2.46, *P* < 0.001). The organizational survey investigated sonologists working in each hospital ([Table 1](#tab1)). There was an overall average of 10.46 sonologists per hospital in China, which differed significantly between Tier 3 and Tier 2 hospitals (20.31 sonologists vs. 6.46 sonologists, *P* < 0.001). Tier 3 hospitals had a higher ultrasonic instrument quality inspection rate than Tier 2 hospitals (97.69% vs. 95.52%, *P* < 0.001).

Regarding educational background, the majority (54.49%) of sonologists had bachelor’s degrees, while 26.77%, 16.32%, and 2.42% had junior college or technical secondary school degrees, master’s degrees and doctoral degrees, respectively. More sonologists from Tier 3 hospitals had bachelor’s degrees or more, while sonologists with a degree lower than a bachelor’s degree usually worked in Tier 2 hospitals (*P* < 0.001). Most (40.44%) of the sonologists in China had the title of attending, followed by resident (35.42%), associate chief (17.89%), and chief (6.26%). The proportion of rankings and educational background differed significantly between Tier 3 and Tier 2 hospitals (*P* < 0.001).

Most (41.35%) of the sonologists in China were 25–35 years of age, and 35.97%, 20.31% and 2.37% were 35–45, more than 45, and less than 25 years of age, respectively ([Figure 3](#fig3)).

### The use of BI-RADS templates in mainland China

The average utilization rate of BI-RADS in Chinese hospitals was 87.02 ± 23.01% ([Figure 4](#fig4)). We analysed the factors that influenced the use of standardized templates for structured reporting of breast ultrasound examinations in Chinese hospitals. The correlation of the Breast Imaging Reporting and Data System (BI-RADS) utilization rate and factors are shown in [Table 2](#tab2). There were significant differences in the utilization rate by ownership of hospitals (*P* = 0.005), tiers of hospitals (*P* < 0.001), category of the hospital (*P* = 0.018), GDP per capita of the province (*P* < 0.001), percentage of doctors with master and doctoral degrees (*P* < 0.001), percentage of doctors <35 years (*P* < 0.001) and quality inspection rate of ultrasonic instruments (*P* = 0.036). However, the percentages of associated chiefs and chiefs were not correlated with the BI-RADS utilization rate (*P* = 0.31).

To assess potential factors affecting the BI-RADS utilization rate, we used a mixed linear model with...
parameters derived from the above statistically significant results. In the multivariate mixed model, the GDP per capita of the province was a significant positive factor affecting the BI-RADS utilization rate ($\beta = 0.0012$, 95% confidence interval (CI) 0.0006–0.0025, $P = 0.008$). Hospital characteristics, including specialized hospitals ($\beta = 0.0276$, 95% CI 0.0103–0.0450, $P = 0.002$) and Tier 2 hospitals ($\beta = -0.0346$, 95% CI $-0.0507 - -0.0186$, $P < 0.0001$), showed a correlation with the BI-RADS utilization rate. In terms of sonologists, the percentage of doctors with master’s and doctoral degrees ($\beta = -0.0346$, 95% CI $-0.0507 - -0.0186$, $P < 0.0001$) and doctors >35 years ($\beta = -0.0462$, 95% CI $-0.0783 - -0.0141$, $P = 0.005$) as continuous predictive variables had a significant correlation with the BI-RADS utilization rate [Table 3].

### Figure 2. Average number of sonologists per 10,000 patients in mainland China.

| Province          | Sonologists (per 10,000 procedures) | Quality inspection rate of ultrasonic instruments | Sonologists (per hospital) |
|-------------------|-------------------------------------|--------------------------------------------------|-----------------------------|
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 20.31                       |
| Hubei             | 1.68                                | 97.69%                                           | 6.46                        |
| Fujian            | 1.68                                | 95.52%                                           | 20.31                       |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 10.46                       |
| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 10.46                       |
| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 10.46                       |
| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
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| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
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| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 10.46                       |
| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |
| Guangdong         | 2.25                                | 96.17%                                           | 10.46                       |
| Guangxi           | 2.00                                | 97.69%                                           | 20.31                       |
| Henan             | 2.00                                | 95.52%                                           | 6.46                        |
| Beijing           | 2.25                                | 96.17%                                           | 10.46                       |
| Shanghai          | 2.00                                | 97.69%                                           | 20.31                       |
| Tianjin           | 2.00                                | 95.52%                                           | 6.46                        |
| Henan             | 1.68                                | 96.17%                                           | 10.46                       |
| Hubei             | 1.68                                | 97.69%                                           | 20.31                       |
| Fujian            | 1.68                                | 95.52%                                           | 6.46                        |

Table 1: The general characteristics of departments and sonologists in different tiers of hospitals.

Yrs, years old.
The breast cancer ultrasound diagnosis accuracy rate in mainland China
The average breast cancer ultrasound diagnostic accuracy rate in Chinese hospitals was $73.64 \pm 20.74\%$ (Figure 3). The factors affecting the breast cancer ultrasound diagnostic accuracy rate were further analysed. The breast cancer ultrasound diagnostic accuracy rate was significantly associated with high GDP per capita, Tier 3 hospital, BI-RADS utilization rate, percentage of doctors with master’s and doctoral degrees, and percentage of doctors $\leq 35$ years ($P < 0.05$) [Table 4]. To identify independent factors, the results of the multivariate logistic regression analysis of the suggestive factors are shown in Table 5. We observed significant positive associations between the BI-RADS utilization rate and breast cancer ultrasound diagnostic accuracy rate ($\beta = 0.072$, 95% CI 0.012-0.133, $P = 0.019$). The GDP per capita of the province was also a significant positive factor ($\beta = 0.028$, 95% CI 0.004-0.051, $P = 0.02$) (Table 5).

Discussion
This survey summarized the current situation of departments and sonologists providing breast ultrasound diagnosis in mainland China, compared the development of departments among provinces with different economic development levels, the labour distribution and hospital types, and discovered the factors affecting the utilization rate of the BI-RADS template and the accuracy rate of breast cancer ultrasound diagnosis in mainland China. This was the first nationwide breast ultrasound study conducted by an official national organization and supported by local governments and health committees in mainland China.
Table 2: Factors associated with the utilization rate of the BI-RADS template in mainland China.

Yrs, years old.
BI-RADS, Breast Imaging Reporting and Data System.
GDP, gross domestic product.
SD, standard deviation.

| Parameters                                | Average ± SD | P     |
|-------------------------------------------|--------------|-------|
| Ownership of hospitals                    | 0.005        |       |
| State-owned hospitals                     | 87.36 ± 22.80|       |
| Privately funded hospitals                | 84.77 ± 24.25|       |
| Tiers of hospitals                        | <0.001       |       |
| Tier 3                                    | 90.43 ± 18.32|       |
| Tier 2                                    | 85.24 ± 24.90|       |
| Category of hospital                      | 0.18         |       |
| General hospital                          | 86.67 ± 22.80|       |
| Specialized hospital                      | 88.55 ± 23.81|       |
| GDP per capita                            | <0.001       |       |
| High                                      | 87.96 ± 22.24|       |
| Low                                       | 85.85 ± 23.88|       |
| Percentage of doctors with master's and doctoral degrees | <0.001       |       |
| High                                      | 89.99 ± 18.70|       |
| Low                                       | 86.62 ± 23.54|       |
| Percentage of associate chief and chief   | 0.31         |       |
| High                                      | 88.53 ± 21.20|       |
| Low                                       | 87.82 ± 22.12|       |
| Percentage of doctors ≤35 yrs             | <0.001       |       |
| High                                      | 88.55 ± 21.22|       |
| Low                                       | 86.19 ± 23.88|       |
| Quality inspection rate of ultrasonic instruments | 0.036       |       |
| High                                      | 87.29 ± 22.82|       |
| Low                                       | 84.96 ± 24.09|       |

Table 3: Mixed linear model of factors associated with BI-RADS utilization rate.

Yrs, years old.
BI-RADS, Breast Imaging Reporting and Data System.
GDP, gross domestic product.
CI, confidential interval.

| Parameters                                | β      | 95% CI           | P     |
|-------------------------------------------|--------|------------------|-------|
| GDP per capita                            | 0.0012 | 0.0006–0.0025    | 0.0080|
| Specialized hospital                      | 0.0276 | 0.0103–0.0450    | 0.0020|
| Privately funded hospitals                | −0.0212| −0.0428–0.0004   | 0.0540|
| Tier 2 hospitals                          | −0.0346| −0.0507–0.0186   | 0.0000|
| Percentage of doctors with master's and doctoral degrees | 0.0476 | 0.0060–0.0891    | 0.0250|
| Quality inspection rate of ultrasonic instruments | 0.0344 | −0.0179–0.0868   | 0.1970|
| Percentage of doctors ≤35 yrs             | −0.0462| −0.0783–0.0141   | 0.0050|

Table 4: Factors associated with breast cancer ultrasound diagnostic accuracy rate in mainland China.

Yrs, years old.
BI-RADS, Breast Imaging Reporting and Data System.
GDP, gross domestic product.
SD, standard deviation.

| Parameters                                | Average ± SD | P     |
|-------------------------------------------|--------------|-------|
| Ownership of hospitals                    | 0.468        |       |
| State-owned hospitals                     | 73.76 ± 20.69|       |
| Privately funded hospitals                | 72.41 ± 21.22|       |
| Tiers of hospitals                        | <0.001       |       |
| Tier 3                                    | 76.36 ± 18.24|       |
| Tier 2                                    | 70.43 ± 22.94|       |
| Category of hospital                      | 0.23         |       |
| General hospital                          | 73.88 ± 20.44|       |
| Specialized hospital                      | 71.97 ± 22.70|       |
| GDP per capita                            | <0.001       |       |
| High                                      | 74.95 ± 19.72|       |
| Low                                       | 71.54 ± 22.12|       |
| Percentage of doctors with master’s and doctoral degrees | <0.001       |       |
| High                                      | 77.87 ± 16.88|       |
| Low                                       | 72.57 ± 21.64|       |
| Percentage of associate chief and chief   | 0.81         |       |
| High                                      | 75.03 ± 19.60|       |
| Low                                       | 74.75 ± 20.04|       |
| Percentage of doctors ≤35 yrs             | 0.047        |       |
| High                                      | 75.27 ± 19.97|       |
| Low                                       | 72.98 ± 20.82|       |
| Quality inspection rate of ultrasonic instruments | 0.974       |       |
| High                                      | 74.12 ± 20.37|       |
| Low                                       | 74.06 ± 20.96|       |
| BI-RADS utilization rate (%)              | 0.001        |       |
| High                                      | 74.92 ± 20.41|       |
| Low                                       | 70.82 ± 20.71|       |
Breast cancer remains a significant cause of morbidity and mortality. Ultrasound is a cost-effective screening modality; however, it depends on the operators for mass assessment. Breast imaging structured reporting templates were encouraged for reporting breast ultrasound examination results. The ACR BI-RADS lexicon helped standardize image descriptions and interpretation reports. The average utilization rate of BI-RADS in mainland China was 87%, which is still unsatisfactory. This finding suggests that the importance of using BI-RADS was not fully recognized by sonologists in Chinese hospitals. Our study found that the high GDP per capita of the province, hospital characteristics, including specialized and Tier 3 hospitals, a high proportion of doctors with master’s and doctoral degrees and doctors ≤35 years had a positive correlation with the BI-RADS utilization rate. Doctors ≤35 years old may have received breast ultrasound training since the beginning of standardized training for national residents in 2015, and the use of BI-RADS is higher. Our data show that well-trained and educated sonologists were concentrated in Tier 3 hospitals, which may lead to higher rates of BI-RADS use.

Previous studies showed that the accuracy of breast ultrasound is as high as 69–93%. We showed that ultrasound performed well in differentiating breast nodules with an accuracy rate of 74%, which was comparable to reported data. With the unbalanced economic development in various regions of the country, our research results also found that the per capita GDP of a province is a significant positive factor for the accuracy of breast cancer diagnosis. Previous studies also demonstrated that ultrasound diagnostic sensitivity and specificity are higher in high-income countries than in low- and middle-income countries. A meta-analysis study, including articles from 2000 to 2018, showed that ultrasound had an overall sensitivity and specificity of 80.1% and 88.4%, respectively. When only data from low- and middle-income country were considered, the sensitivity of ultrasound diagnosis was 75% and the specificity was

| β     | SE  | P     | 95% CI         |
|-------|-----|-------|----------------|
| High GDP per capita | 0.028 | 0.012 | 0.02 | 0.004–0.051 |
| Tier 3 hospital | 0.022 | 0.013 | 0.089 | –0.003–0.048 |
| BI-RADS Utilization rate | 0.072 | 0.031 | 0.019 | 0.012–0.133 |
| Percentage of doctors with master’s and doctoral degrees | 0.045 | 0.025 | 0.077 | –0.005–0.095 |
| Percentage of doctors ≤35 yrs | –0.058 | 0.03 | 0.052 | –0.117–0.001 |
| Constant | 0.679 | 0.035 | <0.001 | 0.611–0.748 |

*Table 5: Multiple logistic regression analysis of factors associated with breast cancer ultrasound diagnostic accuracy rate.*

Yrs, years old.

BI-RADS, Breast Imaging Reporting and Data System.

GDP, gross domestic product.

CI, confidential interval.
was completed by interviewers on the website, which although quality control was implemented, the survey economic development in the region.

The results also showed that the proportion of Tier 3 hospitals was related to the level of highly educated sonologists are concentrated in Tier 3 hospitals. The workforce of Tier 3 hospitals was larger than that in regions with a higher GDP per capita. Moreover, the workload of sonologists in mainland China was not comparable to the data from some countries, such as the United States, because a sonologist in mainland China plays a more prominent role in ultrasound diagnosis and treatment. Some countries, such as Italy and South Korea, have similar practices. In Italy, 1423 examinations (including CT, ultrasound, MRI, etc.) for each employee in the radiology department were performed, whereas the work-charge for each technologist resulted in approximately 2800 diagnostic ultrasound examinations.24–26 The appropriate use of the lexicon should be reinforced, which may improve physician diagnosis and ultimately lead to more appropriate management.

There were 2.25 sonologists per 10,000 patients per year in mainland China. The number of sonologists per hospital and the workload of each sonologist were higher in Tier 3 hospitals. Moreover, the workload of doctors in regions with a higher GDP per capita was greater than that in regions with a higher GDP per capita. The workload of sonologists in mainland China was not comparable to the data from some countries, such as the United States, because a sonologist in mainland China performs both ultrasounds and is engaged in ultrasound diagnosis and treatment. Some countries, such as Italy and South Korea, have similar practices. In Italy, 1423 examinations (including CT, ultrasound, MRI, etc.) for each employee in the radiology department were performed, whereas the work-charge for each technologist resulted in approximately 2800 diagnostic imaging examinations.24–26 There were on average 2.25 sonologists per 10,000 patients in mainland China. Thus, the average annual workload per sonologist was 4444 procedures.

A typical sonologist in mainland China is a 25- to 35-year-old fellow with a bachelor’s degree. Our data found that different tiers of hospitals have different compositions of sonologists, and more high-level and highly educated sonologists are concentrated in Tier 3 hospitals. The results also showed that the proportion of Tier 3 hospitals was related to the level of economic development in the region.

There are several limitations to our study. First, although quality control was implemented, the survey was completed by interviewers on the website, which may affect the accuracy of the information. Some hospitals’ ultrasound information systems are not compatible with the survey, which may lead to data reporting errors. Equivalently sampled hospitals in the analysis might be misleading for some national (or province-level) statistics. The authenticity and reliability of some data need to be improved. The direct capture of quality control data from various medical institutions will be a key focus in the future. Second, all included hospitals were Tier 3 and Tier 2 hospitals instead of community hospitals, which may have led to selection bias. Third, inter-observer variation in BI-RADS categories among different sonologists exists.

**Conclusion**

The use of the BI-RADS template effectively improved the diagnostic accuracy of ultrasound. Moreover, the survey summarized the current situation of departments and sonologists providing breast ultrasound diagnosis in mainland China, and discovered the factors affecting the utilization rate of the BI-RADS template and the accuracy of breast cancer ultrasound diagnosis. These findings can help monitor the development of the discipline and provide information for administrators to meet growing demand.

**Contributors**

W-HY and J-YX conceived of and designed the study. L-JC, GY, G-LY and ML participated in the study design, performed the analysis and edited the manuscript. G-LY were major contributors in writing the manuscript. XW, T-XX, ZR, Z-YX and W-RJ participated in the verification of data, image quality verification, selection, and collection of samples and prepared the figures and tables.

**Data sharing statement**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Declaration of interests**

The authors declare no competing interests.

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Not available.

**Supplementary materials**

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lanwpc.2022.100576.

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