

Smart hospitals around the world: a systematic review

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Research Article

Keywords: Smart Hospital, Digital Hospital, Smart Device, Smart Health

Posted Date: February 22nd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-258174/v1>

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Abstract

Background

It is almost impossible to think about a non-digital world today. digital technologies have changed our life style and they have also affected many domains including health domain. We are all aware that paper-based hospitals have changed a lot to be paper-less. Then a new term was born which is “smart hospital” and studies have been conducted in this field, so this study was designed to conduct a comprehensive review about smart hospitals.

Methods

741 studies were identified using unique keywords through searching in the PubMed, ScienceDirect, Embase and Scopus databases. Overall, after applying the inclusion and exclusion criteria (647 based on abstract title and 33 after reading full text) and removing duplicates (43), 18 studies were included in this review.

Results

Geographically, most of the articles were from Asia (50%). The highest number of publications were observed in 2012. A multidisciplinary team were involved in 77% of the researches and 61.12% of them were conducted in more than one research center. The majority of articles have been published in Q1 quality journals (33.34%) and high-income countries accounted for the largest percentage (66.67) of publishing smart hospital related articles. 27.78% of the studies were aimed at patient care, which had the highest percentage. Among the technologies used, RFID was the most and 66.67% of the articles came from researches about the implementation of a smart hospital.

Conclusions

it should be noted that development or implementation of a smart device in a hospital should not be considered as implementing a smart hospital, while many studies have used the term smart hospital in their study. Many Asian researchers have used the term “smart hospital” in their articles, but on the other hand, most of related articles published in Q1 journals were from America and Europe. Also, it was also observed that most studies focused on the two concepts including resource management and patient care.

Background

Nowadays, digital technologies and systems have affected various aspects of our daily lives so that without them, everything would seem so far from today’s world and out of place in the modern society [1-

4]. The field of healthcare and medicine is one of the areas which has witnessed significant development through using digital tools [5-7]. As an example, smart tools do play an important role in diagnosis and treatment of various diseases[8, 9]. Therefore, development of such technologies and awareness, training and attitude of medical staff and patients in regards to smart technologies have caused creating a new concept called “smart hospital” [10].

“Digital hospital” was firstly introduced with the aim of transferring paper-based systems and patient files to electronic health records (EHR) [11]. Afterwards, the triple concept of care, health and cost was developed in 2007, emphasizing on improvement of care and health while decreasing related costs in every healthcare organization [12]. With the increased acceptance of EHR among the healthcare society, a large volume of clinical and financial data was produced which resulted in improved clinical research, better decision-making for managers and highlighting the need for technological maturity in that era [13]. With the approval of The Health Information Technology for Economic and Clinical Health (*HITECH*) Act in 2009, this use increased exponentially[13, 14]. After a while, the word “digital” was slowly replaced with “smart” and the initial attempts for developing smart hospitals were started and many research studies and operational projects were conducted in this field[10].

One of the necessary conditions for developing of a smart hospital is creation and optimization of clinical and administrative processes along with designing and using novel technologies and equipment. These conditions cannot be met without interconnected assets[15-18]. In this regard, Big Data is an important part in smart hospitals since a large volume of data is automatically produced each moment. Efficient Use of this Big Data can result in improved care and better functionality [19]. Smart Hospitals has changed the way of providing healthcare services which would maximize efficiency, increase care quality, improve existing processes and obtain better patient satisfaction[9, 20, 21].

According to World Health Organization (WHO), the healthcare domain would deal with even more than 18 million healthcare professionals with insufficient skills in the next decade [22]. Along with limited space and human resources which would cause long, high-stress work hours, increasing the number of medical staff is not a sustainable option to meet these daily increasing needs for healthcare services [23]. On the other hand, the ability of smart hospitals in simplification of work flow and better management of patients’ health can help provide better care in response to increased demands, while also rectifying current deficiencies [24]. Also, using novel sciences such as AI[1] to overcome these challenges among developing smart hospitals seems essential [25].

Despite the advantages of using AI and operations automatization, they has been implemented very slowly in several fields including healthcare domain [26]. However, the truth is that there is no way to get away from technological maturity and an ever-increasing use of novel technologies in healthcare in the near future is predictable [27].

Smart hospitals can not only result in improved service provision and quality in hospitals but can also be effective in larger ecosystems such as smart cities for providing healthcare services [28]. Many believe that the concept of “Smart Hospital” includes the use of smart tools in a hospital setting, but it is much

more than that. Actually, smart hospital is a dynamic digitalized environment with a core of artificial intelligence based on many integrated technological innovation which aims to provide maximum and real-time benefits for all connected individuals [19, 29, 30]. Therefore, due to the importance of using smart hospital and considering it as that comprehensive concept, here we aim to provide a review regarding researches conducted on this concept.

[1] Artificial Intelligence

Methods

In the current study, York standard framework (suggested by Arksey and O'Malley) was used to design the overall framework of the study [31] Therefore, the steps in the current study are based on the five steps defined by York including:

1. Identification of study questions;
2. Identification of relevant resources;
3. Careful review of the resources;
4. Data analysis;
5. Gathering, summarizing and reporting of the results.

Each of these steps are explained in the following sections.

1. Identification of study questions

In the current study, three main aspects of smart hospitals include general information, design and economic aspects were investigated. Questions for each aspect were defined through formation of a focus group made from medical informatics experts (three faculty members and two Ph.D. students) (table 1).

Table 1: Study questions and corresponding smart hospital aspects

Aspects	Questions
General Information	<ul style="list-style-type: none"> · What is the distribution of existing articles based on publication year? · What is the distribution of existing articles based on geographical location? · What is the quality of journals publishing these articles? · What is the information of the specialized teams in these articles?
Economics	<ul style="list-style-type: none"> · What is the distribution of the articles based on development index of the publishing countries? · What is the distribution of the articles based on the GDP of the publishing countries?
Design	<ul style="list-style-type: none"> · What is the distribution of the articles based on their goals? · What are the technologies used in these articles? · What is the distribution of the articles based on the type of study?

2. Identification of relevant studies

Search team (SMT, NS, MR) designed a comprehensive search strategy in order to identify and retrieve articles relevant to research goals based on the inclusion and exclusion criteria.

The inclusion criteria included articles in English language published before the year 2021 with no limitations regarding the affiliations of the articles.

The exclusion criteria included review articles, conference papers, letters to editor, books, white papers and articles whose full texts were not accessible.

Search Strategy

It is necessary to determine concepts and keywords for a search strategy [32]. To this end, keywords were selected in the field of smart hospital based on research goals. The keywords used in the search included smart hospital, intelligent hospital and digital hospital.

Search team (SMT, NS, MR) used these keywords to design the following search strategy in title/abstract fields: ("smart hospital" OR "digital hospital" OR "intelligent hospital"). The publication year of the articles was set to any articles published before 2021. Finally, electronic literature search was conducted on PubMed, Science Direct, Embase and Scopus databases.

3. Selection of studies

The research method which is presented as a diagram in figure 1 shows the step-by-step process used to select articles.

After the search, a total number of 741 articles (85 PubMed articles, 131 Science Direct articles, 115 Embase articles and 410 Scopus articles) were retrieved. After removing duplicates (43 articles) 698 articles remained. The search team (MR, NS) then separated relevant articles from irrelevant ones based on inclusion and exclusion criteria. In this step, 647 articles were removed after reviewing the title and abstract of all while for 51 remaining articles, the full text was investigated. After reviewing the full text, 33 articles were extracted from which 18 ones were included in the final study.

4. Data analysis

Two researchers (MR, NS), independently extracted necessary data from retrieved articles based on study questions and study goals. Then, the extracted data from articles were compared. In order to calculate the degree of agreement between two researchers, Kapa coefficient was used which was equal to 0.86. In case of facing lack of agreement between two researchers, the third researcher (SMT) was consulted. The final data was then prepared after evaluation by team members and based on suggestions and comments.

5. Gathering, summarization and reporting of results

A table was used to gather the data extracted from articles in which the rows represented each article and columns indicated the variables. Then, the table was filled with the collected Data.

Frequency analysis is one of the common analysis methods for data sets which shows the frequency of articles based on each studies variable. In the current study, frequency analysis was used to analyze the data set based on each variable and the results were displayed in various graphs.

Results

The results obtained from the current study were categorized based on three aspects presented in table 1 (general information, economics and design). Statistically significant results were categorized according to publication year, geographical location, journal quality, specialized team, study goals, study technology and study type.

Geographical Location

The geographical distribution of published articles is presented figure 2. Asia with a total of 50% of articles has the highest number of publications after which, Europe with 33.34% of articles was in the second place. Among the investigated articles, no one was published in Africa.

Publication Year

Figure 3 shows the distribution of articles based on their publication year. Articles related to mart hospitals were only published from year 2010 onwards. A peak in publication was observed in 2012

containing 6 articles (27%). Based on the search strategy used in the current study, no articles published in years 2013 and 2016 were retrieved.

Specialized team

After evaluating the retrieved studies, various disciplines were observed among the authors of published articles. The majority, 77.77% of the studies used multidisciplinary team (from various fields) while 22.23% has no multidisciplinary team. Furthermore, the results indicated that multicenter studies (studies conducted by more than one research center) made up 61.12% of the retrieved studies while 38.88% were single center studies (figure 4).

Journal Quality

33.34% of the retrieved articles were published in Q1 journals while 22.22% were published in Q2 journals, articles published in Q3 and Q4 journals each made up 16.66% of all and 11.12% of the articles were published in journals not indexed in ISI. Figure 5 shows the distribution of articles based on their journal quality and development level of their countries.

Distribution of articles based on the level of development and GDP of publishing countries

Investigating the published articles based on the level of development as well as GDP of source countries indicated that developing and developing countries has a similar share in the published articles (50%). The countries were also divided into three groups of high, upper middle and lower middle-income countries based on their reported GDP. According to this categorization, 66.67% of the studies were conducted in high income countries, 27.77% were conducted in upper middle-income countries and only one article in the field of smart health was published in a lower middle-income country. (Figure 5)

Distribution of articles based on Study Goal

Evaluating the retrieved studies showed a large variety in the goals of the studies. Therefore, the main goals of the studies were divided into three main categories of patient care, resource management and framework.

As can be seen in figure 6, 27.78% of the studies were conducted with the goal of patient care, 11.11% with the goal of resource management and 11.11% with the goal of framework. Furthermore, studies with combined patient care and framework aims made up 11.11% of the studies while the rest has the combined goal of patient care and resource management (38.89%).

Technologies used in the studies

After evaluating the retrieved articles, 17 out of 18 articles (94%) used different technologies (table 2). These technologies were used to make a section, room or device smart in a hospital.

Study Type

Retrieved articles were categorized based on their type of study through formation of a focus group and were divided into three main categories including implementation, architecture and survey studies. Implementation type articles were aimed at implementation of a specific product in smart hospitals; architecture articles aimed to provide frameworks for smart hospitals and survey articles were those conducting qualitative studies on users and stakeholders of smart hospitals. They were categorized through interviews or written questionnaires. The majority of the published articles in the investigated time period were implementation articles which made 66.67% of the total publications. Architecture articles were in the next place with 27.77% while only 5.65% of the published articles were survey articles.

Discussion

Main Findings

Smart hospital is a complex concept for which numerous definitions have been suggested to date. However, one certain part of all these definitions is that a smart hospital contains a wide variety of smart interconnected nodes which minimizes human role[19, 29, 33]. According to our investigations, the majority of the investigated articles had used the term smart hospital due to its attractiveness and has only used or implemented a smart tool in a small part of hospital environment. This can be concerning since the concept is more expansive than that. This can be due to lack of medical informatics or other similar specialists in the research teams. Since many journals are willing to publish article in this field, studies related to smart hospitals has become an attractive field of study in recent years. Although such studies are valuable, every researcher should notice that those are only a small part of the smart hospital. According to our results, the trend toward smart hospital has been significant, especially in Asia. This is more interesting when we know that the number of articles published in Asia regarding this concept has been higher than in Europe and Even United States. However, the quality of journals used to publish articles from Europe and United States was higher compared to Asia. The majority of the studies published in developed countries were related to implementation of a smart tool which required high financial investments from the research team. The majority of studies were focused on two concepts of resource management and patient care. We aimed to identify the shared aspects of the published studies by answering several study questions. To this end, we suggested to use three categories of general information, design and economics and identified research questions for each of these categories.

General Information

After analyzing 18 retrieved articles, contrary to our expectations for higher number of published articles related to smart hospitals in Europe and United States, the results indicated that Asian countries, especially East Asian ones had conducted a larger number of researches on this topic. This fact, of course, can be explained somewhat through the vast geographical area of the Asia continent compared to that of Europe and United States. The majority of studies on development of smart tools have used RFID and sensors. Based on our search strategies, no studies on the topic of smart hospitals were retrieved in years 2013 and 2016.

Economics

The researchers in developing countries have published their articles on smart hospitals mostly in Q1 and Q2 journals. Unlike developing countries, the results indicated that although developing countries had published a larger number of articles, the majority of these articles were published in Q3, Q4 and other journals. Although the studies in developed countries are mostly conducted in a high quality way, another reason might also be the different opinion of some journals about the quality of data or authors from developing countries compared to the one in and developed countries. One other cause of this difference in quality can be large resource requirements to conduct studies in the field of smart hospitals[34]. Although a high return of investment is predicted in most, large initial investment is often difficult in developing countries with limited budgets and other priorities.

Design

The results indicated that in the majority of retrieved articles, the topics including resource management and patient care had attracted more attention from the researchers since they are mostly considered as important priorities in every healthcare system. Furthermore, investigating the technologies used in different studies indicated that more emphasis has been put on the use of RFID and sensors as smart tools in hospitals which can be due to defining and prioritizing different levels in order to make hospitals smart.

According to the results, the majority of studies focused on the use and implementation of a smart tool in hospitals. A number of studies also talked about the necessary architecture for a smart hospital while only one study investigated the attitudes of stakeholders. Since most studies had investigated the implementation of a single smart tool, it appears that these types of articles are easier to publish, especially when evaluation of the implemented tool is also conducted in the same study. This shows a trend toward the implementation of smart tools among researchers and high attractiveness of this topic to journals.

According to our results, the majority of studies were conducted by researchers with the specialty of computer engineering. Furthermore, implementation of smart tools in hospital settings were mostly done by researchers with different specialties in a multidisciplinary team. This indicates that implementation of such tools in smart hospitals requires the use of specialists from various disciplines [33].

Comparison to other studies

To our knowledge, this is the first systematic review in the field of smart hospitals using the concept of smart hospital as a comprehensive concept.

Limitations

The current study included several limitations. First limitation was the lack of metanalysis due to lack of sufficient details obtained from studies. Second limitation was inclusion of only English articles which

resulted in elimination of some. Third limitation was that due to limited access to search engines in Iran, only databases of Science Direct, PubMed, Scopus and Embase were searched in this study. Searching in other databases may retrieve more results.

Conclusion

The concept of smart hospital is a complex and vast concept and achieving it requires years of cooperation between multidisciplinary teams and following various medical standards. Although this concept has yet to reach its ideal maturity in the current era, due to the rapid technological advances, this future for healthcare services seems reachable. Furthermore, one must notice that implementation of smart tools in hospitals should not be considered as the same as achieving a smart hospital. Moreover, since implementation of smart hospital requires a great deal of investment and has a long return of investment duration, therefore, it is expected that academic researchers with limited budgets are only able to develop and implement smart tools in hospital settings. As a result, development of a smart hospital is only possible by large and credible companies. For example, several companies including HUAWEI CLOUD and Alcatel-Lucent have claims regarding implementation of smart hospitals. The most important service provided by Alcatel-Lucent is the ability of tracking patients' exact locations in order to provide timely and high-quality care. HUAWEI on the other hand, has used Huawei cloud platform to create the triple structure of Communication collaboration, Big Data and AI in a smart hospital setting. The communication infrastructure for this smart hospital uses various technologies including WiFi, optic fibers, 5G internet, microwave communication and eLTE technology. Therefore, it is expected that successful experiences in the field of smart hospitals can act as a starting point to make major changes in functional attitudes and executive methods.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests.

Funding

No funding was provided for this systematic review

Authors' contributions

SMT conceived the study and supervised the article search. SMT, MR and NS drafted and revised the manuscript. All authors read and approved the final draft

Acknowledgements

Not applicable

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Figures

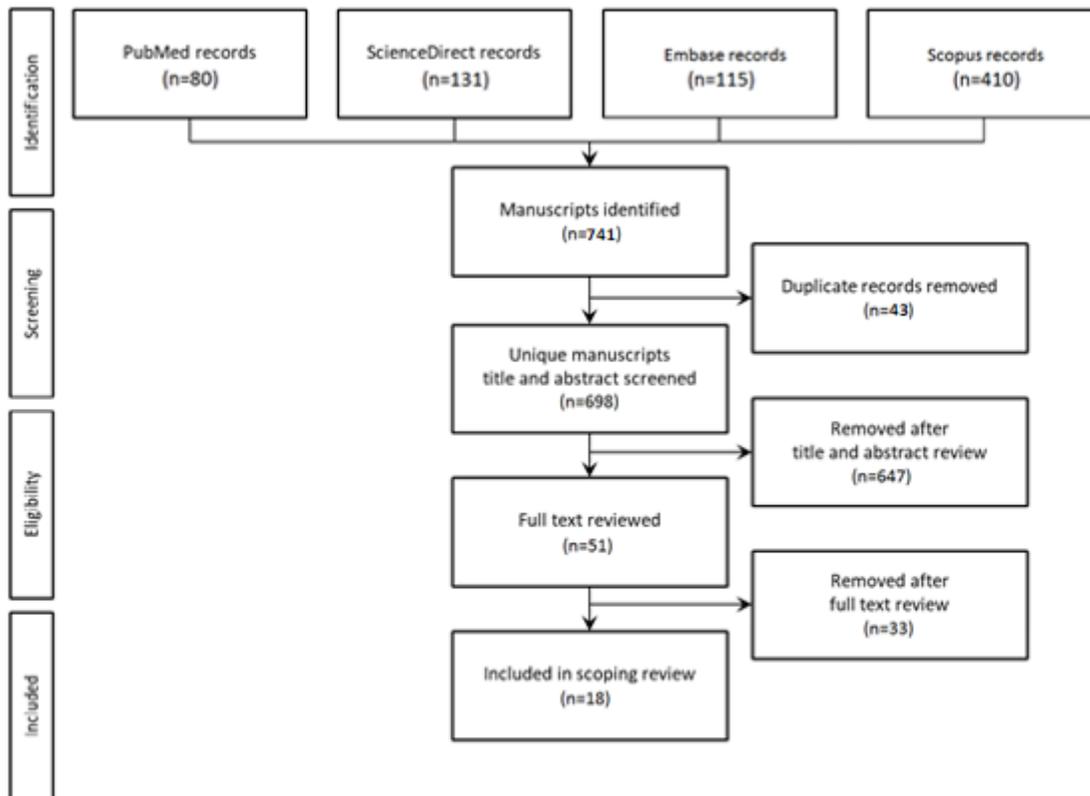


Figure 1: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram of the search methodology;

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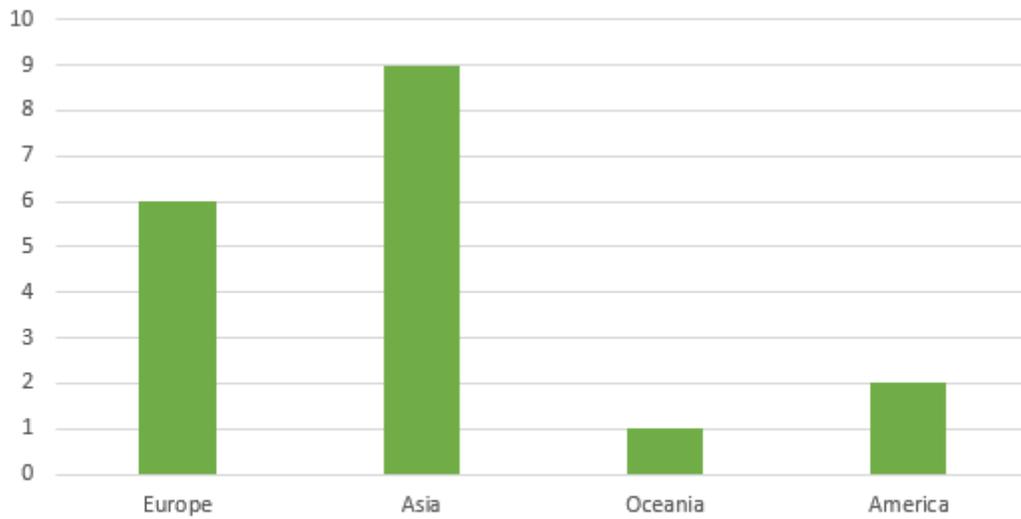


Figure 2: Distribution of studies based on their geographical location

Figure 2

Distribution of studies based on their geographical location

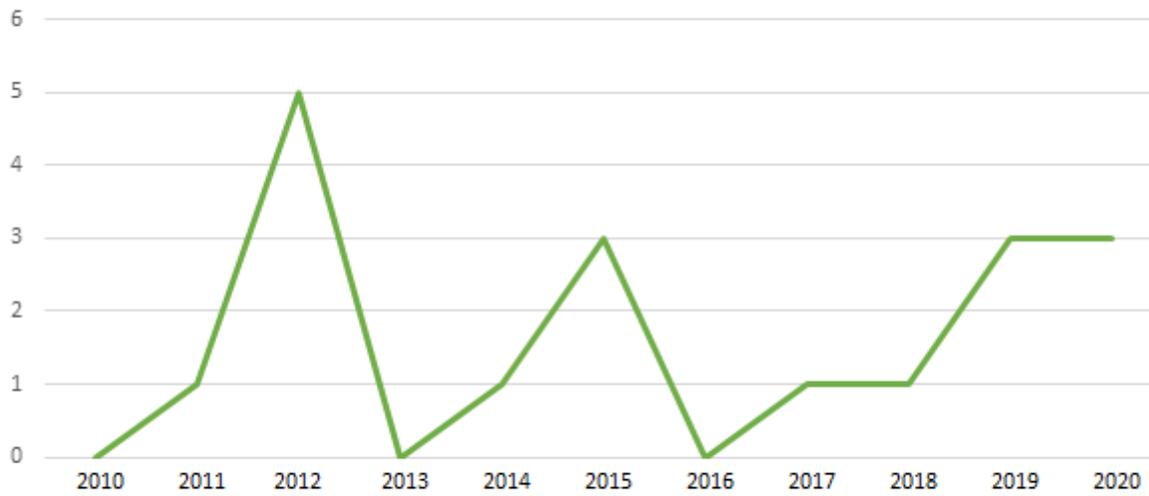


Figure 3: Distribution of studies by publication year

Figure 3

Distribution of studies by publication year

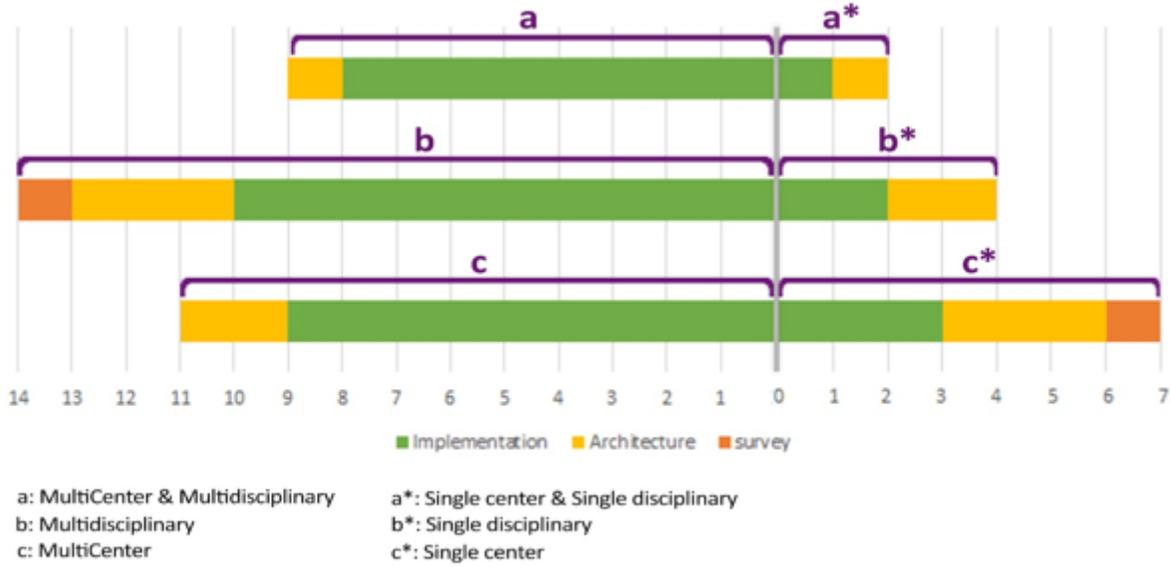


Figure 4: Distribution of studies based on their specialized team

Figure 4

Distribution of studies based on their specialized team

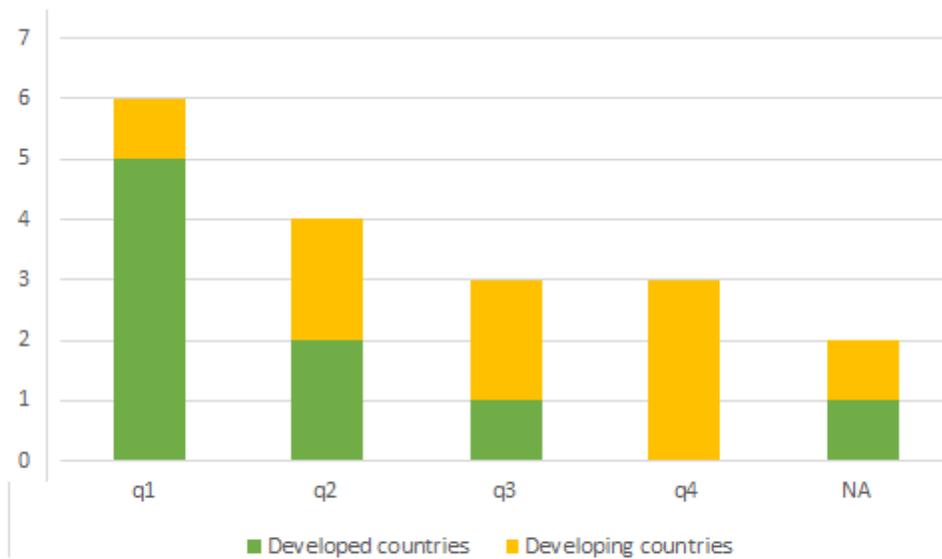
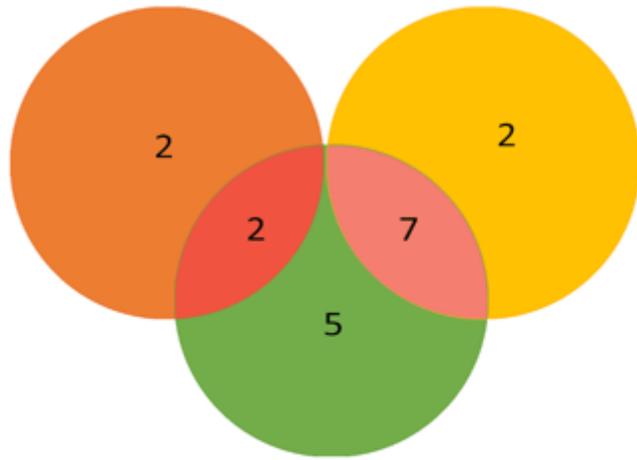


Figure 5: Distribution of articles based on journal quality and country development level

Figure 5

Distribution of articles based on journal quality and country development level



- Patient care
- Resource management
- Framework

Figure 6: Distribution of articles based on Study Goal

Figure 6

Distribution of articles based on Study Goal