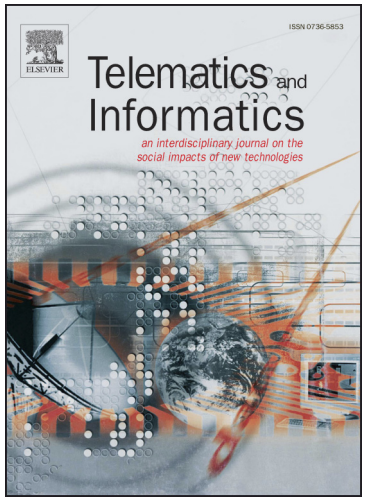

Business intelligence for patient-centeredness: A systematic review

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Abstract: This study utilized a systematic review to provide an overall understanding of how academic research can be incorporated into business intelligence (BI) to ensure patient-centeredness (PC). Using the BI maturity model, this study analyzed findings of previous studies from four time periods within the period 2000–2016 to determine how BI can facilitate PC through organization, human-orientation, and technology, as well as other PC-specific conditions. Our results indicate that the number of BI applications that include PC have continued to grow since 2010, and that they primarily focus on the dimensions of organization, humanism, and PC-specific conditions; additionally, we noted that a time-based correlation exists between the related results. This study then explored the extent to which BI supports the subdimensions of PC (e.g., principles, enablers, and activities). Finally, future research focuses and directions were proposed.

Keywords: Business intelligence; Patient-centeredness; Systematic review; Clinician–patient relationship; Patient involvement; Health data

1. Introduction

Business intelligence (BI), which features superior information technology and management philosophies, can considerably facilitate and drive patient-centeredness (PC) (Oates et al., 2000). Although substantial amounts of data are available in the health care industry, they are not reviewed for hidden information. BI is an established part of health care, and it is hoped that BI can effectively support patient-centeredness. However, BI tools are systematic strategies that require integrating hospitals' existing management systems; therefore, the development and introduction of new BI tools must incorporate managers' strategic thinking and support, as well as various complex challenges such as discrepancies between old and new hospital management systems, the technical skills of internal staff, expectations and demands of external society, integration of internal processes, use of management and clinical data, data quality, and system performance reliability. In addition, cooperation- and trust-related problems arise because of the uniqueness of BI in the field of medicine, the integration and interoperability of clinical and hospital management data, and patient privacy and external policies that influence the sharing of that information between stakeholders. Moreover, controversies concerning the theories and practices of PC-related content and scope remain unresolved (Mead and Bower, 2000; Rawaf et al., 2011; Scholl et al., 2014). Therefore, both theories and practices must be examined to facilitate the effective use of BI systems and tools. However, knowledge is lacking regarding what the difficulties of BI are for PC, and confusion exists about whether BI can truly make full use of health care data, how PC can be supported, and what conditions are required. Thus, this systematic review identifies where in the relevant literature these topic are described. Section 2 introduces the theoretical background of BI- and PC-related studies. Section 3 outlines the present study's methods, analyzes the existing literature, and uses the BI maturity model and four dimensions (e.g., organization and humanism) to determine the current situation regarding BI maturity in the field of medicine. Section 4 discusses the study results, which indicate that PC dimensions are used as the standards for exploring BI in medicine. Section 5 presents the conclusion and offers some potential directions and

areas of focus for future research.

2. Theoretical Background

2.1 Business Intelligence

Luhn (1958) defined BI as "…a collection of activities carried on for whatever purpose, be it science, technology, commerce, industry, law, government, defense." In a broad sense, the BI system is a "communication facility serving the conduct of a business." Currently, most BI-related theoretical studies are divided into two types. The first type highlights the concept of a data center and advocates the use of BI to combine "operational data with analytical tools to present complex and competitive information to planners and decision makers" (Negash, 2004); its goals are to improve data quality and the timeliness of decisions during decision-making. The second type emphasizes the idea of a process center, in which organizations themselves are viewed as "process integration." BI should be used to integrate the information world with the process world and thereby facilitate decision-making with an all-embracing information basis. Following developments in technology, Chen et al. (2012) offered conceptual models BI1.0, BI2.0, and BI3.0, specifying applications for the various model stages, and identify future challenges.

In general, BI features four major functions: data analysis, data warehousing, business performance management, and user interfacing (Negash, 2004; Chen et al., 2012). Of these, data analysis and data warehousing demonstrate the technical properties of BI. Information technology (IT) developments enable business managers to effectively convert data into knowledge and make BI a reality; thus, Chen et al. (2012) maintained that big data is an evolution of traditional BI. Data warehousing is the basis of realizing modern BI, particularly for real time-related technologies (Farooq, 2013). By contrast, business performance management and user interfacing demonstrate the application functions of BI. In medical fields, BI can help facilitate hospital management and treatment decisions, as well as provide high-quality health care by improving human–computer interaction interfaces. The advanced technical functions of BI (i.e., data mining and multidimensional data analysis) allow massive, unused data to be converted into knowledge, providing in-depth support to hospital management and decision-makers. In addition, medical BI systems provide hospitals

with personalized data formulation plans (which demonstrate respect for patient individuality), enhance medical safety and quality control, optimize medical procedures, encourage teamwork among medical personnel, elevate work efficiency, improve medical services, quantify hospital performance, and refine hospital management. Such improvements help achieve PC, fulfilling the goals of patient safety and favorable medical service quality (Iqbal et al., 2016).

2.2 Patient-Centeredness

PC philosophies were introduced during the 1970s, and have since undergone rapid development. PC-related theories and practices gradually evolved beyond the aspect of physiology, in which patients are studied from social and psychological behavior-based perspectives; the concept of combining various care methods (e.g., patient-, individual-, person-, user-, and family-centered care) has also emerged. Although PC is primarily proposed as a physician- or disease-centered concept, its true implications remain unknown. In general, PC dimensional models are used instead of the conceptual meaning of PC. For example, Brown et al. (1995) provided a comprehensive description that includes six interconnecting components (the disease and illness experience, the whole person, common ground, prevention and health promotion, the doctor–patient relationship, and the availability of time and resources). Additionally, Mead and Bower (2000) proposed five key dimensions of PC (biopsychosocial perspective, the patient-as-person, therapeutic alliance, sharing power and responsibility, and the doctor-as-person). Other scholars have emphasized the patient–doctor relationship and communication (Stewart et al., 2003; Epstein et al., 2005). Most recently, Scholl et al. (2014) have identified 15 dimensions that can be divided into principles, namely enablers and activities, and suggested that these dimensions are interrelated. Based on a study by Delphi, this research team has identified the five most important dimensions, namely the patient as a unique person, patient involvement in care, patient information, clinician-patient communication, and patient empowerment (Zill et al., 2015).

From an empirical research perspective, Castro et al. (2016) presented an overview of the antecedents, attributes, and consequences of PC, which link to the dimensions above. For example, the antecedents may include the individual participation, communication, interdisciplinary teamwork, and supportive care environment. The attributes can include biopsychosocial perspective, the patient as a

unique person, a sustainable and genuine patient–care giver relationship. The consequences include knowledge, health behavior, adherence, health outcome, and quality of care. To explore the link among these variables, several tools have been used to measure PC and PC attributes. Some scales measure the broad holistic concept of PC (e.g. the Universal Patient Centeredness Questionnaire and the Individual Care Scale); others are focused on the subcomponents (e.g. the climate and shared decision-making). As discussed earlier, a number of PC empirical referents have contributed to the literature (Hilbert and Yaggi, 2017).

Concerning the methods by which advanced BI management philosophies can be used to realize PC, these concepts have been explored both theoretically and practically. Most of the problems experienced during BI applications comprise technological, human, or procedural problems (McKinney and Hess, 2012; Kao et al., 2016). Some scholars have analyzed the ability of BI to achieve PC by using a technological perspective; for example, Horvath et al. (2011) investigated the ability of the Duke Enterprise Data Unified Content Explorer (DEDUCE) to improve and enhance analysis quality. By contrast, Mettler and Vimarlund (2009) analyzed how collaboration, knowledge, trust, institutions, and governance strengthened BI usage efficiency using the human perspective. A disease perspective was adopted by Sebillo et al. (2015) to study the use of mobile phone- and sensor-based individual data in the daily management of patients. Notably, the authors proposed that the daily medical records of patients with diabetes be combined with multidimensional regional intelligence systems to fulfill PC. However, it is the overall and procedural perspectives that have become the mainstream approaches when performing such analyses. Using the BI maturity model, Brooks et al. (2015) proposed a medical field-based BI maturity model and 15 subdimensions or procedures. A review of recent research regarding the applications of multiagent systems in health care was conducted that included five subdomains (planning and resource management, decision support and knowledge-based processes, data management, remote care/self-care, and multifunctional multiagent systems) and three systems within each subdomain. These researchers also extracted some parameters of these systems, which were compared to analyze the systems' merits and deficiencies.

3. Method

Collecting papers about BI and PC across a broad range of related academic literature from multiple sources is challenging. Fortunately, a systematic review is often viewed as an effective method by a variety of disciplines to help gain a comprehensive view of topics of interest (Wu et al., 2015; Liu et al., 2016; Wu and Shen, 2016; Wu et al., 2017). In this study, a systematic review of English papers published between 2000 and 2016 was conducted.

3.1 Search Strategy

Because BI research is primarily published in information systems journals, PC research is also typically published in health care journals. Similarly, numerous journals in the computer and psychology domains focus more on BI and PC as a combined topic. Therefore, the identified studies examined in this study were retrieved from the following databases: Medline, Cochrane Library, PsycInfo, PubMed, ACM Transactions, IEEE Xplore, and Web of Science. Google Scholar provides a platform through which to search scholarly articles from various research publishers (https://scholar.google.com); thus, we used it as our main search platform.

3.2 Sample and Inclusion/Exclusion Criteria

The inclusion criteria were based on the concepts of PC and BI, in which the BI frame work supports PC. Therefore, the sample of studies had to meet the following inclusion criteria. First, the studies had to include either BI or PC concepts; some relevant terms related to BI or PC had to also be considered. Second, the studies had to explore the relationship between BI and PC concepts. For example, in the BI-related literature, the 12 dimensions of the health care BI maturity model are utilized to investigate how organization, technology, humanism, and other PC-specific conditions and supporting factors influence the framework BI. In the PC-related literature, PC-related dimensions are used as constraints to analyze whether BI conditions facilitate the realization of PC.

3.3 Literature Search

A systematic search was conducted between November and December 2016

using the search terms "PC," "BI," and their related terms (S1, Table 1). Published articles were routinely screened and the list was updated until December 31, 2016. Overall, the online search yielded 17,300 results. The second step (S2) primarily involved usingd the BI maturity model (Brooks et al., 2015), as well as its related dimensions, to select BI literature abstracts that meet the inclusion criteria. The third step (S3) mainly addressed the PC dimensions (Scholl et al., 2014) to select literature related to PC or the three major PC dimensions that meet the inclusion criteria. In the fourth step (S4), restrictions were placed on language and publication year to meet the inclusion criteria.

All of the steps in the exclusion, inclusion, and searching of the abstracts were conducted by two researchers and then verified by a senior researcher. Two independent coders were used to ensure the reliability, with a Kappa value of 0.871, indicating strong reliability among the coding. Next, the reliability of each coder was determined; the resulting Kappa value was 0.854, suggesting a sound consistency within the coding team. Finally, a manually searched reference list of retrieved articles was formulated to locate relevant literature not previously identified.

Table 1 Literature search parameters.

Steps	Web of Science (BI or PC terms)	ACM Transactions, IEEE Xplore, Web of Knowledge (BI terms)	Medline, Cochrane Library (PC terms)	PsycInfo (BI or PC terms)
S1	Data analysis system/ Business intelligence	Business intelligence/ Data analysis system	patient-centered + /OR patient-centered+ /patient-centeredness	patient-centered + /OR patient-centered+ /patient-centeredness
S2	BI "vision strategy" /"management support"/ "learning"/"knowledge management"	BI "project management" OR "change management" OR "data quality "	BI "clinical data"/ "external data" / "human skill" +PC	BI "administrative data"/"clinical data"/ "external data"/ "data integration"/ OR "teams" +PC
S3	PC principles/enablers /activities + BI	PC principles/enablers /activities (e.g., patient information)	PC principles/enablers / activities (e.g., patient involvement in care)	PC principles/enablers /activities, (e.g., communication, emotional support)
S4	Limiters: Date of publication (2000–2016); English language	Limiters: Date of publication (2000–2016); English language	Limiters: Date of publication (2000–2016); English language	Limiters: Date of publication (2000–2016); English language

3.4 Search Outcomes

Using the "BI," "PC," and "related terms" keywords, our online search yielded 17,300 results. With reference to the healthcare BI maturity model, we retrieved 1654 papers; however, 1540 papers were excluded because they do not discuss BI according to PC dimensions. Following a review of the abstracts, 114 papers were selected for full text review. A total of 60 of the included studies primarily focus on BI, 74 focus on PC, and 20 focus on both. The combined search strategies produced 89 articles that meet the inclusion criteria (Fig.1).

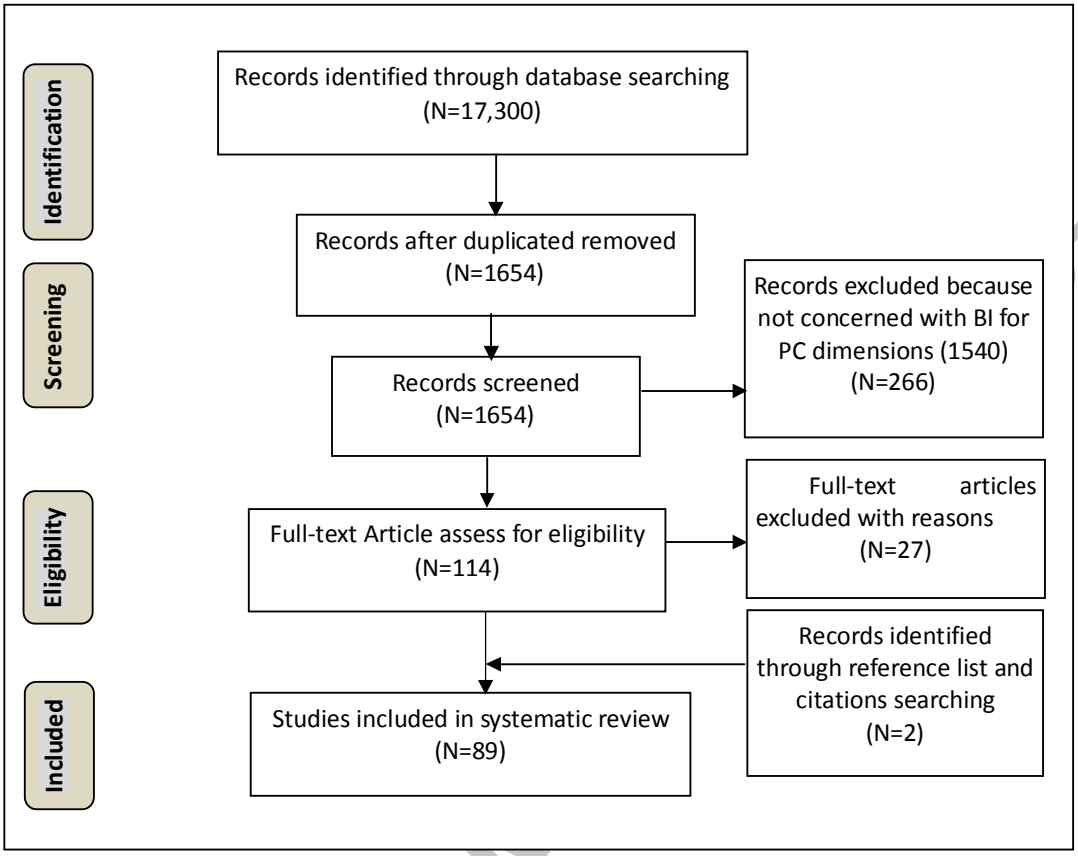

Fig.1. Search strategy

To analyze the text extensively and explore the interaction of the highest frequency words (Heimerl et al., 2014), we used Word Clouds in Atlas.ti V8.0 to obtain a visualization of the 89 papers. Fig. 2 indicates the keywords with frequencies exceeding 500 times. Fig. 3 shows words occurring more than 100 times. Among them, Care (Frequency = 4112), Data (Frequency = 4011), and Health (Frequency = 3910) were found to be the highest frequency words. This indicates that our search strategy can obtain the ideal results and be a good fit for the research topic. In addition, there other words were found to occur more than 1000 times, including patient, information, clinical, management, team, support, outcome, research, system, quality, can, and use. These refining words and related research variables highlight the main trends of the studied papers.

Fig.2. Word Cloud analysis (Frequency >500)

Fig.3. Word Cloud analysis (Frequency >100)

3.5 Data Analysis

Two researchers independently searched for studies, using the BI maturity model's cord category as a framework to uncover the success of BI applications. Next, related subdimensions of the maturity model (i.e., organization, humanism,

technology, and PC-specific conditions) were set as the standards to divide the 89 studies into categories, as shown in Table 2. The results reveal that the related studies mostly explore PC implementation from the perspectives of organization, humanism, and PC-specific conditions; few investigate PC implementation from the perspective of BI technology.

A total of 20 (22.5%) organization-dimension studies were found, most of which were published after 2010. These studies performed analyses focusing on organizational strategy, vision, management support, and organizational environment, yielding a wide range of results. For example, Van Der Wees et al. (2014) argued that patient-reported outcomes (PROs) are the standard for measuring patient status, and an integrated collection of PRO data improves PC and hospital performance. Notably, to use PROs effectively, the main parties (i.e., health care providers, purchasers of care, and patients) must trust each other and share the same vision. McCausland (2012) noted that current health and medical care systems have become increasingly PC-based. Moreover, he argued that caregivers should fulfill their roles in such a care system, particularly those who are nurse leaders and chief nursing officers, because they are the major contributors to a care system's success.

Similarly, Arlotto (2010) stated that senior management personnel such as chief information officers and chief financial officers (CFOs) are key figures in determining whether health information technology for economic and clinical health (HITECH) is achieved. The effective use of electronic health records (EHRs) is invaluable in financial reports, and the CFOs who understand this and participate in HITECH activities are of utmost importance. Later, Murphy et al. (2013) asserted that nurses in senior managerial positions should focus on developing information infrastructures as part of their strategies to ensure that valuable information necessary to making decisions can be obtained from data analytics. Moreover, they contend that such decisions determine treatment results.

Angst et al. (2012) introduced an IT-based structure–process structural framework that improves the communication problems in medical systems. Specifically, IT management systems, such as automatic record tables and electronic file templates, are presented to improve communication, successfully showcasing and achieving medical service improvements. Finally, Glaser and Overhage (2013) presented the four aspects of group learning in the field of medicine: decision-making guidance, process and implementation, organization arrangement, and result and

impact assessments. The researchers further note that when using IT as a learning organization environment, suppliers must consider the feasibility of the tools and technologies used to support knowledge management.

Of the four types of studies, a total of 28 (31.5%) humanism-dimension studies were found to have been published between 2010 and 2014. Contrary to the organization-dimension studies, which adopt a perspective of strategic thinking and yield fruitful results, the human-dimension studies examine how BI processes for PC can be understood from a human perspective, and from the perspective of team skills and project and change management abilities. A considerable range of results were found. Most recently, Brooks et al. (2015) argued that conventional hospital management models will no longer be applicable once BI systems are introduced, because such systems will revolutionize conventional hospital operation processes and organizational cultures. Thus, concepts such as patient-centered medical homes (PCMH) and patient-centered medical villages have begun to garner attention, and the effects of a medical team's abilities and literacy on practical BI introduction processes are being emphasized (DeVoe and Sears, 2013). In addition, studies on process-based change management have mainly investigated how improving medical demand forecasting abilities, medical planning abilities, and medical resource dispatch abilities affects hospital operation processes once BI is introduced.

Myers and Green (2004) and Finarelli (2004) have identified the key role played by hospital demand forecasting ability. However, because medical demands differ between regions and patient groups, accurate medical demand forecasts are markedly complicated. In addition, the lack of related forecast data renders overall research more difficult. Notably, by introducing BI systems, these data prediction problems are resolved. Furthermore, resource dispatch pressures experienced by hospitals prior to the introduction of BI systems primarily occur because of the gap between hospitals' medical resources and patients' service demands (Worthington and Utley, 2012). Therefore, some scholars have maintained that by using BI systems, decision-makers are able to accurately predict medical demands; knowing information such as the number of hospital beds in a facility, availability of hospital staff, number and usage rate of operating rooms, and available diagnostic equipment enhances the medical resource planning abilities of decision-makers (Cardoen et al., 2010; Day et al., 2010).

However, despite the fact that BI systems can improve hospitals' medical resource planning abilities, the facilities' limited resources inhibit the allocation of medical resources according to medical demands when related costs are considered. Therefore, the dispatch of medical resources remains a problem for hospitals.

Additionally, to reduce costs and solve conventional hospital management problems, future studies should focus on identifying the method by which BI systems can be utilized to facilitate medical staff scheduling (Hassmiller and Cozine, 2006), the dispatch of resources in operating rooms (Denton et al., 2010), and the transfer and management of medical records. Ensuring patient appointment efficiency is also one of the core objectives of patient-centered management. Contrary to medical resource dispatches, patient appointments enable predictions and subsequent scheduling. The goal is for hospitals to reasonably arrange their medical resources according to patients' treatment demands (as made by the patients in advance), thereby minimizing patient waiting time and medical resource idle time (Bosch and Dietz, 2000; Green and Savin, 2008). Therefore, improving patients' appointment efficiency through the use of BI systems is one of the key goals of BI for PC.

A total of 14 (15.7%) technology-dimension studies were found. To use technology for improving data structure and quality, the United States passed the HITECH Act in 2009, in which scholars infer that the basis of BI system analyses is database management. In other words, data collection, extraction, and analysis technology determine the success or failure of BI systems (Chaudhuri et al., 2011). Effective data warehousing (e.g., using the DEDUCE model (Horvath et al., 2011)) has become a critical measure for integrating administrative and clinical data (Wisniewski et al., 2003), and the use of research and survey data to enrich clinical data has become the essential method for achieving PC. Many scholars involved in studying service decision-based support systems (Delen and Demirkan, 2013) have attached substantial importance to the use of health information exchanges to purify multisource-based, isomeric, and multimode-based systems, as well as to correcting incoherent grammar and semantics (Vest and Gamm, 2010), and employing big data analysis technologies to enhance medical treatment data quality in medical treatment decision-making. Klann et al. (2016) examined data extraction, transformation, and loading-related challenges in medical networks, and subsequently introduced the integrated biology and bedside (i2b2) project to facilitate barrier-free data conversion between medical networks. Some researchers have also applied big data analysis to

wearable technology, and proposed big data and concrete data warehousing building paths (Khalifa and Zabani, 2016; Wu et al., 2016).

A total of 27 (30.3%) PC-specific conditions-dimension studies were found, most of which were published after 2010, with substantial increases in the number of studies published in 2015. These studies employed BI in PC to facilitate the effective use of EHR and analyzed how BI could be used to achieve PC through the dimensions of "use of administrative data and clinical data," "integration of administrative and clinical data," "exchange with external data," and "interoperation with external data." Marked variation in the results of these studies was noted. For example, Hayrinen et al. (2008) listed more than 10 types of EHR, stating that the EHR comprises unstructured text and structured coded data. In another U.S. study, related research was conducted using the national hospital ambulatory medical care survey, veterans affairs, and veteran health administrative data (Damschroder et al., 2014). Between-country comparisons demonstrated that U.S. hospitals generally have the lowest mortality rates, shortest stays, and highest readmission rates (Bottle et al., 2013). Through mandatory programs and networks, patients received a variety of care, such as nursing care and pharmacovigilance-based care (Curtis et al., 2014).

Additionally, many scholars have begun to pay attention to data warehousing, comparative effectiveness research, PROs data research, and clinical data research networks. Bovitz et al. (2016) stated that it is possible to use heart failure claims to assess left ventricular ejection fraction. On the basis of the New York City Clinical Data Research Network (NYC-CDRN), Kaushal et al. (2014) stated that the organizational structure and cooperative governance model of the NYC-CDRN can benefit PC, hospitals, and even public health.

Various studies have maintained that administrative data is a useful complement to clinical data (Bovitz et al., 2016). For some special diseases, administrative databases contain a wealth of related clinical data that can facilitate further treatments and the realization of PC (Hall et al., 2014). The medical data maturity model establishes the standards for data conversion and collaborative use. Flott et al. (2016) proposed a medical data-based five-dimensional maturity model, emphasizing the continuity of care maturity model, and stating that data interoperability, data exchange, patient participation, and cooperative medical treatment are the basis for measuring whether EHR has been successfully used. Finally, Esmaeilzadeh and Sambasivan (2016) argued that health information exchange (HIE) assimilation

involves more than organizational adoption decisions and the installation of required hardware, software, and infrastructures.

Table2. Articles on the BI Process for PC

Year	Publications								Publications % on total	
	Organization	%	People & team	%	Technology	%	PC-specific	%	Total	%
2000-2004	0	0	4	14.3	0	0	2	7.4	6	6.7
2005-2009	1	5	7	25	3	21.4	1	3.7	12	12.5
2010-2014	14	70	15	53.6	7	50	16	59.3	52	58.4
2015-2016	5	25	2	7.1	4	28.6	8	29.6	19	21.3
Total	20	100	28	100	14	100	27	100	89	100

To identify the correlations between prior studies' results and their research content at various times, the present study used an additional time dimension to analyze the contributions of relevant literature to various PC dimensions. Specifically, the results of these previous studies, which were obtained at different times, were separated into various categories, as indicated in Table 3. Notably, studies that explore the use of BI to improve PC accumulate after 2010, which may be because of the recent rapid application and research development of IT technologies and BI in related fields. Moreover, because the results of these studies were applicable, they evolved from proposals and case studies to analyses of factors of influence and strategic recommendations. Subsequently, scholars have paid substantial attention to the positive effects of BI on PC and adopted various study methods to derive extensive knowledge. However, research on both concepts has largely remained theory- and case study-based according to our literature review; the successful use of BI in PC, as well as the evolution of theories into laws, are currently lacking.

Table 3. Research Trends of BI for PC

Year	Study categories and focuses			
	Organization	**People & Teams**	**Technology**	**Specific to PC**
2000–2004		Offer an ideal model: Hospitals require reformed patient-demand-based management philosophies, which enable BI systems to conveniently store hospital operation data as well as minimize patient waiting time and medical resource idle time.		Description of the vision: 1. Determine the effects of patient-centered data (e.g., quality of life) on their treatment through case reporting; 2. Build effectivedata warehousing to facilitate the integration of administrative and clinical data from technical perspectives.
2005–2009	Achieve PC through successful case implementation (Mayo, 2009), which is made possible through strategic management	Propose specific difficulties or obstacles. Employees' abilities to analyze big data become key for hospitals to achieve patient-centered management and precise medical treatment through BI systems.	Focus on the collection, storage, analysis, processing and management, and application of data (e.g., such as the passing of the HITECH Act (2009) in the United States.	Administer specific PC data analyses to classify the various EHR categories (e.g., unstructured text and structured coded data).

2010–2014	Concrete, strategic analyses: 1. Propose implementation strategies for strategic management, based on the obtained empirical study results. For example, to realize patient-reported outcome applications, the trust and shared visions between health care providers, purchasers of care, and patients are established; 2. Employee resistance and management changes are critical to the implementation of information systems. Therefore, upper management support (e.g., use of philosophies and concrete behavior) is necessary; 3. Explore how to create effective knowledge to build an information sharing and learning environment.	Generate positive change through BI-based reform management philosophies: 1. Facilitate improved medical demand predictions through BI; 2. Enhance hospitals' planning abilities by introducing BI systems; 3. Enhance patient appointment efficiencies through the introduction of BI; 4. Establish PC medical homes.	Introduce adaptive strategies from various dimensions: 1. Identify how to realize medical dataisomorphism ; attach appreciable importance to the use of HIE to purify multisource-based, isomeric, multimode-based systems, and correct incoherent grammar or semantics. 2. Employ big data analysis technology to enhance medical treatment data quality in medical treatment decision-making services; 3. Integrate and unify various network data structures.	Find ways to convert data into information：1. Use management data to realize PC and analyze the diverse functions of Taiwanese databases, as well as those from other countries; 2. Clinical data include both patient-reported and clinical observation data. These data are built and subsequently used in PC; 3. Consider the growing technologies and hospital team, through data integration and interoperation.

2015–2016	Devise adaptive strategies by analyzing factors of influence: 1. Analyze the factors influencing management support; 2. Determine how to create knowledge management environments, key factors, and concrete adaptive measures (e.g., by setting examples).	Propose strategies: 1. Primary care physicians rarely use EHRs because they lack the necessary training and related system maintenance abilities. 2. Introduce project management to enable the use of BI systems in patient-centered, high-efficiency hospitals.	List adaptive strategies and problems to be solved in the future: 1. Because of the number of stakeholders involved, the leveraging of health information technologies remains markedly difficult; 2.Employing big data analyses in wearable technology or proposing concrete big data and data-warehousing-based building paths; 3. Realize health-analytics-as-a-service through cloud technologies.	Enable data to become the support conditions or research model during information and knowledge formation processes: 1. Utilize management and research data to realize PC (e.g., improving PC-based facilities and imaging research); 2. Develop clinical data-related technologies. Integrate outdated information systems and PC data warehousing; 3. Integrate and interoperate data. Consider data interoperability, medical data maturity models, and HIE research.

4. Discussion

The aforementioned four-dimensional BI maturity model serves as a framework of analysis. Theoretically, the maturity of BI in an industry is conducive to PC development; however, whether the maturity of BI in PC is conducive to the development of PC in practice requires an assessment of related results. Therefore, in this study, the contributions of related studies were explored; specifically, the PC dimensions or content introduced by Scholl et al. (2014) were used to analyze the contributions of 89 papers on PC.

4.1. BI Processes for PC Principles

The building of principles in PC can involve various organizational strategies and cultures. Currently, many countries propose the use of medical IT and data to optimize medical processes and qualities, and numerous hospitals advocate for the use of PC in their strategies and philosophies. The goal is to collect valid data and promote patient participation via informatization and mobile technologies (Weston

and Roberts, 2013). However, most contemporary studies have focused on case analyses, and argued that the building of a PC culture is based on big data analysis technologies and a strategy implementation process involving continuous team governance learning (McCarthy et al., 2009; Paulheim and Bizer, 2014). This type of study result is thus relatively inapplicable to PC, which emphasizes viewing patients as unique people, involves comprehensively assessing patients' perceptions during the treatment process, and requires that relevant strategies be implemented during the environmental design, medical treatment, and late stage patient–hospital interaction processes.

In addition, because of scholars' inconsistent understanding of PC principles, related studies have been unable to effectively indicate how BI can be used to achieve PC. Four primary reasons help explain this limitation. First, PC emphasizes human-oriented processes; however, because people's medical treatment demands are complex, reaching a consensus between hospital units, formulating a vision, and winning support from all sides is difficult to achieve in the short term. Second, the biopsychosocial perspective indicates that PC can only be achieved through multidisciplinary collaborations among the fields of psychology, sociology, and biology. However, interdisciplinary research and integration require doctors and researchers with high literacy skills. Third, numerous promotion platforms and conditions are required to achieve PC principles, thereby placing additional demands on hospitals and society. Fourth, there are few instances of the establishment of PC cultures and philosophies using the latest short-term management science (e.g., project and knowledge management) is lacking. Therefore, the question is raised of how to practice treating patients as people and other PC principles in the digital era. This necessitates that hospitals deeply explore and discuss the organizational management, cultures, people, and other factors related to big data function.

4.2. BI Processes Toward PC Enablers

Various factors, such as the "depth" of social organizations and institutions; provision of convenient, timely, and continued medical treatment from hospitals; abilities and literacies of medical teams; and effective patient communication platforms and support conditions determine how BI can be used to build PC enablers. Therefore, regarding theories, scholars have devoted themselves to building PCMH, and have introduced NYC-CDRN in practice (Kaushal et al., 2014). Since 2012, the Patient-Centered Outcomes Research Institute has built a number of PC outcomes

research networks and dedicated itself to introducing hospital-management-related reforms and innovations. However, related research that focuses on changing management philosophies and the BI field has seldom explored the methods for enhancing the abilities of relevant medical personnel. These conditions pose substantial challenges to personnel training and development in the medical industry, because the ability of personnel to analyze big data is key for hospitals looking to implement BI systems and subsequently achieve patient-centered management and precise medical treatment. Scholars have thus adopted a project management perspective and divided the application of BI systems into three stages: preimplementation, implementation, and post-implementation (Sangar and Iahad, 2013). However, to date, no literature has been published on the use of project management methods in BI system applications to facilitate high-efficiency, patient-centered hospital management. Following a review of previous studies (Chuah and Wong, 2011; Brooks et al., 2015), we similarly assert that the effective implementation of BI systems can be divided into the three aforementioned stages. During the pre-implementation stage, hospitals should consider how BI systems can be used to achieve patient-centered management, formulate overall strategic plans, and select appropriate BI system agents. During the implementation stage, hospitals should set specific business operation blueprints according to patient-centered management needs and set up and test BI systems, particularly patient communication platforms and other support conditions. Finally, during the post-implementation stage, hospitals should optimize and assess BI systems and perform regular maintenance, repairs, and updates as required.

In addition, the medical industry data structure and quality should lend technical support to PC. Because medical data isomorphism is a notable problem in both data analyses and mining, data warehousing must be built and existing data must be effectively mined prior to introducing BI; such endeavors are also the prerequisites of patient information management. These actions must be taken to achieve effective medical decisions, enhance medical safety, increase patient satisfaction, and improve hospital performance. Although existing studies have focused on data acquisition, storage, analysis, processing and management, and application (Chang et al., 2008; Brinkmann et al., 2009), they have rarely delved into the use of data to achieve high-efficiency PC hospital management. In such systems, BI big data services can be classified into three data service modes, namely “data as a service,” “mining as a

service," and "analysis as a service" (Delen and Demirkan, 2013). However, because ownership of data resources is not clearly defined at present, data security and privacy protection remain major problems in big data resource-based developments and usage (Clifton and Marks, 1996). Moreover, given that medical-treatment-based big data involve patients' private information such as health information, hospitals should have strict guidelines in place when using BI-based big data information services.

4.3 Applying BI to PC Activities

PC activities include patient information, patient empowerment and involvement in care, the involvement of family and friends, and clinical support. These activities must be performed by humans. To use BI systems, related personnel and teams must possess a range of skills, including data analysis, business management, and IT skills; such skills determine whether data can be converted into information and knowledge. For example, Holve et al. (2012) analyzed the challenges and opportunities associated with the development of electronic clinical data infrastructure to support CER; notably, the challenges remain unresolved. In addition, once BI is introduced, patient empowerment and involvement conflicts with existing hospital management models. Thus, the building of medical teams' abilities and literacies, including physicians' attitudes and self-positioning, becomes particularly critical after BI is introduced. This is particularly the case for certain treatment decisions that require considering individual needs, preferences, and values—for example, obstructive sleep apnea (Hilbert and Yaggi, 2017). By enhancing patient education and support to improve treatment adherence, patient engagement and continuity of care can be achieved. By implementing PCMH, improving physician quality, and facilitating authorizations, physician–patient trust can be established (Wong et al., 2016). Finally, the introduction and implementation of BI is a systematic and continuing process. Thus, hospitals must use the latest management philosophies, such as project management, to effectively use BI and achieve PC management.

5. Conclusions

This study conducted a systematic review to provide preliminary research on BI for PC. Numerous articles located on electronic databases were collected and reviewed to outline current knowledge regarding BI for PC. One major finding is that

the quick development of BI and PC is based on BI maturity model-related studies, which explore organization, humanism, technology, and PC-specific conditions. Notably, these studies involve refining future visions and introducing case studies, gradually developing into analyses of influencing factors and strategic recommendations. This results-oriented literature evaluates the contribution of BI to the research development of PC, from a PC perspective. Overall, theoretical research using BI philosophies to understand and achieve PC has only recently begun, notably since 2010.

However, external society and organizations provide corresponding platforms for hospitals' PC development, thereby accelerating the introduction and application of BI in the medical field. Relevant parties have also proposed new expectations and demands for PC from multiple dimensions, and PC philosophies have thus gradually become assimilated. Current research has focused on the positive effects of BI on PC, and several methods have been used to extract extensive information. Nevertheless, no overall theory has been established regarding the successful implementation of BI in PC experiences to upgrade theory to law. The main obstacle is that trust and cooperation are required from multiple parties during the data–information–knowledge process, particularly in the medical field. Data exist in several fields and organizations, including social organizations, hospitals, and commercial institutions, and the collection and storage of data are based on varying objectives and functional requirements. However, the strong functions of BI can be weakened because of these different perspectives, a lack of collaboration philosophies, and slow advances in cooperative governance studies, resulting in insufficient theoretical exploration.

Finally, the results of this study offer researchers and practitioners an overview of current research trends and reveal new research directions. The first insight from a PC specific perspective indicates that the major concerns lie in the integration, exchange, interoperability of administrative, clinical and external data. Because administrative data are biased toward hospital finances, they have been criticized for their insufficient focus on clinical data, patient perception, and medical research. Similarly, simple clinical data may be unable to determine treatment results. External data (e.g., concerning insurance and government) are based on social objectives or functional requirements, and are subject to a greater difference in data structure and quality. Thus, enabling BI to find a way to use data without having to exert

integration efforts (extraction, transformation, and loading) for each new organization or object is a crucial topic for researchers and practitioners. Secondly, technology, particularly that involving IT factors in the medical field, has also attracted attention and in-depth study because it determines the use of BI functions (Yeoh and Popovič, 2016; Shen et al., 2017). In the United States, the government spends considerable financial resources on establishing medical network infrastructures, such as the Scalable Collaborative Infrastructure for a Learning Healthcare System. Systems such as this require health IT to develop corresponding applications to improve patient-centered outcome research methods and capacity of care functions. Finally, the organization and its personnel must pay more attention to the climate and culture of medical teams and hospital services.

This study has some limitations. To focus the scope of the literature review, our search only collected studies that contributed to understandings of mature research frameworks in the existing literature. Thus, some necessary references and results may have been overlooked. Future studies should expand this scope or focus on specific topics for further in-depth analysis.

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Highlights

- Since 2010, literature related to the introduction of BI to the medical field has grown rapidly
- The addition of academic research has evolved gradually into concrete strategic recommendations
- Based on previous research, this study investigates the extent to which related literature has examined PC philosophies