Review Article

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Development and Progress of Pharmacoinformatics in Pharmaceutical and Health Sciences

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ABSTRACT

The aim of this study is to identify and review literature that presented information about development and application of pharmacoinformatics in pharmaceutical and health sciences. The quality assessment tool for quantitative studies suggested by Cochrane Collaboration was adopted in this review. Independent assessment was conducted to evaluate the quality of the included studies. A databases used for this study and review was PubMed and Science Direct. Both databases search was conducted using the English key words, "pharmacoinformatics", "pharmacy informatics", "medical informatics", "health informatics" and etc. The search strategy resulted in the inclusion of sources, the majority of which expert opinion and examines the pharmacoinformatics relevance from a theoretical point of view (PubMed, n=72). Based from the keyword of "informatics" and "pharmacy" on PubMed databases using advanced search, 59 articles was obtained with particular fields which is title and abstract. The articles are then being filtered by article type, publication dates and languages of articles. The article type which is clinical trial (n=2) and in review articles (n=7). The articles has the range of publication dates which is 10 years (n=34) and 15 years (n=72). The rapid development of internet has led to the pharmacoinformatics technologies to assist the pharmaceutical care and health-related outcomes. Based on the study, it can be concluded that pharmacoinformatics has a lot of advantages and uses especially in pharmaceutical and health sciences.

Key words: Computer, Health informatics, Internet, Information system, Medical informatics, Pharmacy informatics.

INTRODUCTION

There are many different languages of the term informatics was established during 1950's and 1960's; informatik (in German 1957), informatics (in English 1962), informatique (in French 1962) and informatika (in Russian 1966). These words denote the study of the design, application, function and effect of information and communication technology.[1,2] Studies in informatics are connected with the information concept.[3] Pharmacoinformatics is equivalent to medical informatics in which the information and communication technology relates any aspect of drug delivery, from the basic sciences to the clinical use of medications.[4,5]

Generally, pharmacoinformatics can be defined as the combination of drug information and pharmacy

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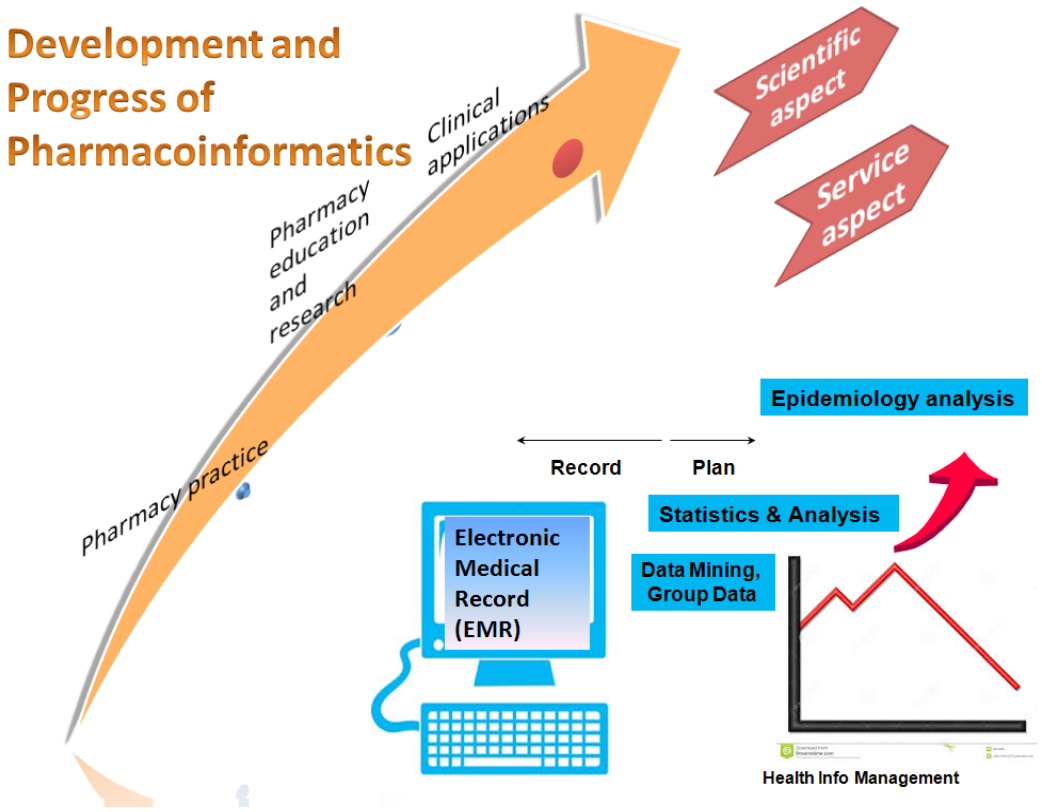

Graphical Abstract

information systems.[6] It is also included in the scope of medical informatics and drug discovery which related with the drug's properties and management of the drug's properties.[7] There is another new information technologies instead of pharmacoinformatics such as toxico-informatics, neuroinformatics, immunoinformatics, cancer informatics, chemo-informatics, bioinformatics, metabolomics, genome informatics, proteome informatics and biomedical informatics.[8] The study of pharmacoinformatics is categorized into two aspects which are scientific aspect and service aspect. Firstly, the scientific aspect involves the management of the drug discovery and drug development activities. Secondly, the service aspectincludes patient-centered care.[8] To meet the future need, it is expected that improvement in the reliability and diversification of information technology be carried out which may propel pharmacoinformatics as a vital element of pharmaceutical science.[8]

Pharmacy and informatics

Nowadays, the roles of pharmacist in delivering care have been assisted by integrating many technologies for pharmacy practice.[9,10] A new specialty within the pharmacy practice which is pharmacy informatics provides a new career path for the pharmacist who has an interest for computers and information technology in order to support pharmacy activities.[11,12] Information technology which increases efficiency may reduce the time for the pharmacist to prepare and dispense medication, as well as more time for the pharmacist to handle the clinical activities.[13] The pharmacy system includes patient-specific clinical data to support the relevance of medication review, conduct real-time inventory management, and cooperate with other systems.[11,14]

Pharmacy informatics for pharmacist profession

Pharmacists denote pharmacy informatics as "*A scientific scope that apply a system approach to medication-related data information including its acquisition, storage, analysis and dissemination in the delivery of optimal medication-related patient care and health outcomes*".[15] Pharmacists have been regularly applying computers and automation since 1980s to complete many tasks in providing care to patients. Pharmacists have been routinely utilizing computers and automation since the 1980s to complete many tasks in providing care to patients.[15] All graduate pharmacy students should possess the knowledge and skills of pharmacy informatics for the medication use process.[16] Pharmacist must use the technology effectively and possess a variety of computer skills for the improvement of patient care.[13,17]

The pharmacist profession generally caters for the needs of accurate information and knowledge, for instances the knowledge about medications, patient and disease status as well as the medication use process. In order to have strong clinical skills, pharmacist must arm with the skills of utilizing information resources effectively to provide quick and optimal patient care.[18] Pharmacists must also highly computer and information technology literate to manage the high volume of information.[17] As a result, many pharmacists practice pharmacoinformatics on a daily basis. Some technologies which is currently used in their practice are clinical decision support system (CDSS), computerized prescriber order entry, bar code systems and electronic prescriptions which have tremendously enhanced the pharmacist's work efficiency and performance.[15]

Pharmacoinformatics in pharmacy practice

Development and application of pharmacoinformatics within the drug delivery for the purpose of research and clinical use of medication may improve the drug utilization for individuals and for the society.[1,19] This involves invention and implementation of technology related to the drug delivery, from the basic sciences to the clinical use of medication in individuals and populations. In the health care delivery system, there is preparation, delivery and management of medication use which is also included as pharmacy technologies.[8] Pharmacoinformatics may be used in the purpose of study about the development of the electronic prescribing and dispensing processes of drugs whether in medical practice, follow up or research.[20] Some studies are applying pharmacoinformatics to assess the risk of prescribing errors for e-Prescriptions compared to non-electronic prescription.[21,22] Pharmacoinformatics used to analyze the changes and co-variation between polypharmacy and potential drug interaction over a few decades and to assess the related risk for actual drug combination.[1] In a new national pharmacy for clinical medical practice, follow up and pharmacoepidemiologic research, pharmacoinformatics is used to describe the information content.[23,24] Pharmacoinformatics is also used to study a regional, individual-based prescription database by investigating the frequency, distribution and determinations of potential drug interactions.[1,25] Medical informatics such as pharmacoinformatics concerned with modeling, controlling and simulation of the drug properties to achieve explicitly therapeutic requirements towards each patient.[7] Information technology has promoted the pharmacy advance, the progress of pharmacoinformatics technology leads to model changes of medical productivity and pharmacy practice, improve the ability of health-care workers to apply the medical information and promote the development of medical information economics.[10,26] For the past 15 years, tremendous progress and development had been achieved. Thus, the objective of this study is to identify and review the literature that presented information about development and application of pharmacoinformatics in pharmaceutical and health sciences.

Table 1: MeSH term used

➢ **Informatics**
▪ Medical Informatics
-Medical Informatics Applications
a) Decision Making, Computer-Assisted
b) Decision Support Techniques
c) Information Storage and Retrieval
d) Information System
❖ Health Information System
❖ Hospital Information System
❖ Management Information System
e) Management Information System
-Medical Informatics Computing
Entry terms :
•Informatics, Medical
•Health Informatics Technology
•Health Information Technology
•Information Technologies, Health
•Technologies, Health Information
•Medical Computer Sciences
•Science, Medical Computer
•Computer Science, Medical
•Clinical Informatics
•Informatics, Clinical
•Information Science, Medical
•Medical Information Science
➢ **Drug Information Services**
▪ Adverse Drug Reaction Reporting System
▪ Clinical Pharmacy Information System
▪ Pharmacovigilance
Entry terms :
•Services, Drug Information
•Information Services, Drug
•Drug Information Service
•Service, Drug Information

METHODS

Criteria used to consider reviews for inclusion

Pharmacoinformatics is a very broad and general terms thus a comprehensive search of medical subject heading using PubMed was performed. The subject headings included in this study is represented in (Table 1).

Other requirements for the studies are as following:

- The study should be written in English language
- Primary source, such as research, project report,

Table 2: Search databases and search terms used

Search databases	Keywords/Search terms
PubMed	#1 ?informatics [Title/Abstract] #2 pharmacy [Title/Abstract] #1 AND #2 (n = 59) #3 pharmacoinformatics [Title/ Abstract] Filters : published in the last 15 years #1 AND #2 OR #3 (n = 72) Date : All articles published in a range of 2000 to 2014.
Science Direct	Pharmacoinformatics Pharmacy Informatics Pharmacy AND Informatics Pharmacy OR Informatics Medical Informatics Health Informatics Date : All articles published in range of 2000 to 2014.

literature review, theoretical analysis, discussion paper, textbook, etc.

- Non-primary research articles that were published only as an abstract, review, commentary or letter were excluded from the review.
- The study is determining the importance of pharmacoinformatics topics in pharmaceutical and health sciences.

Search methods for the identification of reviews

Major widely used electronic databases were selected for the search, including PubMed and Science Direct (from 2000 to December 2014).

The search method depends on the selected year which is last 15 years from now as the requirement for this review. Last 15 years articles are believe as the most latest and updated information about pharmacoinformatics and its development as well as application. It is also depends on the availability to access to the electronic databases from the Universiti Teknologi MARA computer laboratory in which the searches were performed. A search strategy was designed using a particular search terms. For PubMed, the medical subject headings (MeSH) 'informatics', drug information', and 'pharmacoinformatics' were used (Supplementary File 1).

Data extraction and management

Potential articles obtained from the searching strategy based on a few keywords were independently assessed on its titles and abstract for eligibility. Differences in decisions about inclusion and exclusion were resolved through consensus and a few considerations. A pre-developed data abstraction form was used to extract the following information from the included studies: the study title, author(s), country, year, objective(s), the statistical methods used to assess the importance of pharmacoinformatics study in pharmaceutical and health sciences, the results, and the authors' conclusions.

Assessment of the methodological quality of the included reviews

The quality assessment tool for quantitative studies suggested by Cochrane Collaboration was adopted in this review. Independent assessment was conducted to evaluate the quality of the included studies.

Data synthesis

This review used the narrative synthesis. Meta-analysis was considered to be inappropriate and unsuitable because of the heterogeneity of the studies in terms of methods, participants, settings and outcomes. The synthesis step began with the organization of the extracted data by the author. A narrative description of the most common factors identified from the review were reported and discussed in the results and discussion sections.

Data sources

A databases used for this study was PubMed and Science Direct. Both databases search was conducted using the English key words, "pharmacoinformatics", "pharmacy informatics", "medical informatics", "health informatics" and etc. as presented in (Table 2).

RESULTS

Description of the included reviews

The search strategy resulted in the inclusion of sources, the majority of which expert opinion and examines the pharmacoinformatics relevance from a theoretical point of view, (PubMed, n=72) and a few articles from Science Direct based on the searching keywords in (Table 2) (pharmacoinformatics, pharmacy informatics, medical informatics etc). Based from the key word of "informatics" and "pharmacy" on PubMed databases using advanced search, 59 articles is obtained with particular fields which is title and abstract. The articles were then being filtered by article type, publication dates and languages of articles. The article type which is clinical trial (n=2) and in review articles (n=7). The articles has the range of publication dates which is 10 years (n=34) and 15 years (n=72).

Characteristics of the included reviews

(Table 3) shows some of the available articles assessed for this review to identify and determine the study that presented information about development and application and the use of pharmacoinformatics in pharmaceutical and health sciences.

Table 3: Included articles that presented information about development and application of pharmacoinformatics

Author(s)	Year	Title
Barnett and Jennings[10]	2009	Pharmacy information systems in Canada
Bennani *et al.*[11]	2007	Medical informatics in Morocco : Casablanca Medical Informatics Laboratory
Bharatam *et al.*[12]	2007	Modeling and informatics in designing anti-diabetic agents
Chauhan *et al.*[13]	2012	Comparative analysis of different DNA-binding drugs for leishmaniasis cure : a pharmacoinformatics approach
Collier *et al.*[14]	2009	A rheumatology-specific informatics-based application with a disease activity calculator
Dixon *et al.*[15]	2014	An informatics approach to medication adherence assessment and improvement using clinical, billing, and patient-entered data
Fox *et al.*[6]	2011	Knowledge, skills, and resources for pharmacy informatics education
Fox *et al.*[8]	2008	Pharmacy informatics syllabi in doctor of pharmacy programs in the US
Goldmann *et al.*[16]	2014	Exploiting open data : a new era in pharmacoinformatics
Hope[17]	2007	Influence of pharmacy informatics on research
Lin *et al.*18	2008	Pharmacy informatics in controlled substances research
Matsuura and Weeks[19]	2009	Use of pharmacy informatics resources by clinical pharmacy services in acute care hospitals
Serafim *et al.*20	2010	Assessment of informatization for the dispensing of medication at a university hospital
Siska and Meyer[21]	2008	Pharmacy informatics : aligning for success
Talbert *et al.*[22]	2005	An incremental pharmacy informatics model for use in a rural hospital
Tanaka[23]	2005	Pharmacoinformatics and pharmagenomics
Traynor[24]	2012	Pharmacy informatics aids cancer center care
Traynor[25]	2013	Informatics group sees role for pharmacy in insurance exchanges
Tribble *et al.*[26]	2009	Whither pharmacy informatics
Yap *et al.*[27]	2009	Improving pharmaceutical care in oncology by pharmacoinformatics: the evolving role of informatics and the internet for drug therapy

DISCUSSIONS

The objective of this review is to identify the studies that had presented information about application and the use of pharmacoinformatics in pharmaceutical and health sciences. Studies were included if their main objective were to explore and study the pharmacoinformatics. Pharmacoinformatics is a very broad and some general terms which include medical informatics, health informatics or pharmacy informatics.

Pharmacoinformatics clinical applications

Diabetes mellitus which indicate the overproduction of glucose and glucose underutilization is a chronic metabolic disorder. Insulin injection is injected subcutaneously for the treatment of Type I diabetes mellitus.[27] Delivery method of injected seems quite disturbing for a diabetic patients since it can causes pain and hurt. Therefore, pharmaceutical researcher still in progress to work on other delivery method which is oral delivery of insulin in tablet form by using pharmacoinformatics approach.[28] Molecular modeling and informatics studies on drugs associated with Type II diabetes mellitus such as virtual screening, quantum chemical studies and pharmacoinformatics were also used.[19] Pharmacoinformatics techniques somehow is used for the comparative analysis of different DNA-binding drugs for leishmaniasis cure.[29] Besides, pharmacoinformatics may include the use of informatics, the internet and interactive technologies to solve drug related problem which highlight on providing optimum pharmaceutical care and improved the safety of the patient. In addition, pharmacoinformatics may increase the efficiency and improve the pharmaceutical care of patients with cancer. The evolving role of informatics and the internet for drug therapy may improve pharmaceutical care in oncology by pharmacoinformatics.[30] Health-care has increasingly evolved with the informatics revolution applied the opportunity of integrating pharmacoinformatics in the practice of clinical oncology to solve drug related problems. Some study describes an integrated informatics approach to

identify problems with medication adherence and facilitate the communication strategies between patient and provider about the medication use.[12]

It is noteworthy, the role of pharmacy informatics specialist had emerged in acute care hospital.[31] The use of clinical pharmacy informatics in patient care in acute care hospitals is significantly more likely when a pharmacy informatics specialist is present in the pharmacy.[32] There is also an incremental pharmacy informatics model for use in a rural hospital.[33] The next generation of medical informatics for patient safety which is hospital rules-based system enhances the identification of drug related problem.[34]

Pharmacy education and research

Professional pharmacy programs providing formal pharmacy informatics education is crucial to train pharmacy student and practicing pharmacist on this area[35,15,36] Doctor of pharmacy programs and all graduating pharmacy students should possess knowledge and skills in the informatics education as following requirement in the 2007 Accreditation Council for Pharmacy Education Standards and Guidelines.[16] Doctor of pharmacy programs in the US has implemented the pharmacy informatics syllabi which helps the students to be able to utilize information technologies in practice to improve medication-related outcomes.[15] Instead of pharmacy informatics, clinical informatics is also important for the pharmacy students. Effective teaching of clinical informatics in undergraduate teaching of health informatics should be highly interactive.[37,38] Before developing an interactive approach in teaching pharmacy informatics or medical informatics, the study of the existing medical informatics course offered for students is being conducted.[39] Pharmacies have become an important component in support of clinical research. Application of informatics in clinical research will result in more efficient operation of research.[32]

Meanwhile, in an attempt to provide safe and efficient supply chain management, the U.S. Food and Drug Administration has introduced the usage of drug pedigree.[40] The reason behind the introduction of drug pedigree is that to clarify the drug originality in the supply chain.[41] However, only 22.5% of the Unites States hospitals get the verification of drug pedigree from their primary wholesaler.[41] Drug pedigree can be an important tool used to prevent the counterfeit drugs from entering the supply chain.[42] Chemical and physical identifications like the composition of excipients and impurities, morphology and thermal identification, can serve as a 'marker' in identifying counterfeit drugs.[43] Usage of near-infrared spectroscopy technology in detecting counterfeit drugs also may provide a very quick screening.[44] The effort in detecting counterfeit drugs is somehow difficult due to complicated and non-uniform nature across the world distribution system.[45,46]

Pharmacy informatics in hospital

The rapid development of information technology also leads to the benefits of electronic prescribing and inventory control used in hospital.[47] e-prescribing or electronic prescribing is a method in which the prescription is undergoing the process of generation, transmission and receiving of the prescription from the prescriber to the dispenser by using electronic access.[48] The usage of e-prescription in the outpatient setting has enabled uninterrupted transmission of prescription to the pharmacies and hence avoiding dispensing error and enhances safety and efficacy.[30,41] E-prescription also allows information such as patient's medical history to be shared among the clinicians.[49]

A brief history about e-prescriptions is that they came out in two generations. The first generation of E-prescription includes a paper based prescription which also includes a barcode on that paper.[48] This kind of prescription was started on February 2005 and starting from that time, 99% of the prescribers are able to produce e-prescription and 86% of the pharmacies are able to receive the prescription with the utilization of the software. The second generation of e-prescription is a prescription that depends solely on electronic transmission, in which they avoid the traditional use of paper based prescription and link to the specified prescriber was also provided on the prescription.[48] The application of second e-prescription was started on 2009, and it is used widely throughout the pharmacies in England on August 2012.[48] From Asia perspective, for example in Malaysia, e-prescription system were used on 21 facilities of government health clinics and all hospitals starting from March 2013.[50,51] In a study done to evaluate the adoption and use of pharmacy informatics in all hospitals in the United States on 2007, it was found that among the hospitals with e-prescription system, 44.0% of the hospital had implemented CDSS to enhance prescribing process.[41] The CDSS provide supportive information likes drug choices and patient medical records,[41] and pop-up window will emerge when possible drug-drug interaction or allergic reaction is detected.[30,52] A survey done on 2007 in the United State found that, 42.9% of the hospitals has electronic medical record (EMR), out of which 5.9% with complete EMR.[41] Majority of the hospitals that is 90.7 % of them enabled pharmacist to have an access

the data to help them in handling medication therapy, but only 56.7% of the hospitals enabled the pharmacist to report in the EMR.[41] Meanwhile, 15% and 81% of hospitals in Riyadh region of Saudi Arabia implement total and partial EMR systems, respectively where the pharmacists monitorpatients' medication therapy constantly.[36] In some developing countries, however, the implementation of total Hospital Information System (HIS) possessed some problems due to poor information technology facilities, insufficient hard work as well as challenges in providing an acceptable software and hardware.[50,53] By any means, the HIS provided in the hospital setting should conform to criteria like it should have an acceptable security control of the data supplied, it is also should be usable in all branch of the health system.[20,54] The vendors which supply those software and hardware also should possess standardization in terms of its accumulation, coding of data and the method involved in transferring the data.[55,56]

Information technology also makes the inventory control becomes easier. Wise management of drug inventory is very crucial so that drug shortage problem could be prevented. For example, in a study done on 2007 in the United States, it is found that 95.6% from all hospitals in the United States ordering drugs from the primary wholesaler through the use of internet, while 34% of them also made the ordering of schedule II items online.[41]

Meanwhile, problems in drug shortage may affect patient care and lead to disruption of medication order process.[25,57] The use of the technology-operated system such as radio frequency identification and bar codes offers advantages on the pharmacist's role in controlling inventory. On 2007, a study done in United States found that 29.9% of the hospitals use bar codes technology and 2.0% of the hospitals uses radio frequency identification.[41] The bar codes can be generated on numbers of items by using the pharmacy information system.[58,59] This is beneficial so that all items can be scanned by the medication storage and distribution devices.[60] With the advancement in technology, new efficient technology could replace the existing one and hence helping pharmacist towards better work performance.[58,59] For example, most of the hospitals in United States used decentralized distribution system with a percentage of 52.7%.[41] This type of distribution system use automated dispensing cabinet that was interfaced with the pharmacy information system.[41] The decentralized system is also characterized with the use of satellite pharmacies so that drug distribution process can be done smoothly.[61]

CONCLUSION

The rapid development of internet has led to the pharmacoinformatics technologies to assist the pharmaceutical care and health-related outcomes. Based on the study, it can be conclude that pharmacoinformatics has a lot of advantages and uses especially in pharmaceutical and health sciences. Pharmacoinformatics has a purpose which maximizing the benefits from the use of information systems and technologies. Pharmacoinformatics also has the purpose related with the properties of the drug and management of the drug properties. Pharmacoinformatics may enhance the pharmacoeconomics context of decision-making. In addition, pharmacoinformatics is a basic tool for the purpose of drug discovery. In the needs of future, there will be more improvement in the information technology scope, thus pharmacoinformatics may become a vital and basic element of pharmaceutical science.

CONFLICTS OF INTEREST

All authors have no financial or competing interest.

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ABBREVIATION

CDSS: Clinical decision support system
MeSH: Medical subject headings
U.S.: United States
EMR: Electronic medical record
HIS: Hospital Information System

Highlights of Paper

- The rapid development of internet has led to the pharmacoinformatics technologies to assist the pharmaceutical care and health-related outcomes.
- Pharmacoinformatics optimize the benefits from the use of information systems and technologies.
- Pharmacoinformatics may enhance the pharmacoeconomics context of decision-making.
- With improvement in the information technology scope, pharmacoinformatics may become a vital and basic element of pharmaceutical science.

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