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Designing a standardized framework for data integration between zoonotic diseases systems: Towards one health surveillance

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ABSTRACT

Background: Zoonotic diseases or zoonoses account for a considerable ratio of infectious diseases outbreak; their effective surveillance demands coordinated actions by human and animal health organizations. However, zoonoses surveillance data are collected individually from standalone information systems for either humans or animals with varied structures, processes and applications. In moving towards one health (OH) surveillance, integrating the zoonoses data may help prevent and control these diseases. Therefore, this research aimed to determine essential data elements and a consistent reporting template towards interoperability.
Material and methods: In this study, first, the zoonotic diseases minimum dataset (ZD-MDS) was identified according to a comprehensive literature review coupled with the agreements of experts. Then, the ZD-MDS was mapped to structured clinical vocabularies. Also, the health level seven-clinical document architecture (HL7-CDA) standard was used to define the interoperable and human-machine reporting template.
Results: The ZD-MDS was divided into administrative and clinical sections with five and seven data classes and total of 38 and 57 data elements, respectively. Then, the corresponding data values and systematized nomenclature of medicine-clinical terms (SNOMED-CT) codes were defined for each data element. The reporting template was structured according to three sections of CDA template, extensible markup language (XML) hierarchical and tags.
Conclusion: Our study suggested that zoonoses surveillance could be improved by integrating and exchanging data from different databases across humans and animal organizations. The developed template provided a comprehensive and interoperable dataset, making data more comparable and reportable across multiple studies and settings.

1. Introduction

Zoonotic diseases or zoonoses are contagious diseases that are naturally transmissible from animal hosts (usually vertebrates) to the human population, or vice versa [1,2]. Statistically, it is appraised that nearly 60% of pathogens affecting humans are of animal origin. More than 70% of novel pathogens likely to be used in bioterrorism attacks are zoonosis [3,4]. Despite developing preventive and controlling strategies for zoonoses management, many countries, including Iran, suffer from a widespread outbreak of these diseases [5,6]. Most of the emerging zoonotic diseases, including extremely pathogenic avian influenza, NIPA virus, Middle East respiratory syndrome coronavirus (MERS-CoV), severe acute respiratory syndrome (SARS), Coronavirus disease 2019 (COVID-19) and pH1N1 (H1N1 epidemic), have triggered severe contagions worldwide [7]. Zoonotic diseases also constitute a significant and devastating threat to the public health and the globalization trade of animal and animal products. Still, their influence is often misapprehended due to inadequate surveillance measures and lack of sufficient data on their significance and burden [8–10]. In Iran, due to isolated organizational performance, weak and traditional surveillance and reporting systems, traditional agriculture and livestock breeding, climate changes and rural living have caused a substantial proportion of contagious diseases to be zoonotic[11]. For successful implementation and operation of zoonotic diseases surveillance system (ZDSS),

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Table 1
Search syntax.

Databases	Search syntax
PubMed	((((((("Zoonotic"[Title]) OR ("Zoonoses"[Title])) OR ("Zoonosis"[Title])) AND ("registry system" [Title/Abstract])) OR ("information system" [Title/Abstract])) OR ("surveillance system" [Title/Abstract])) AND ("data field" [Title/Abstract]) OR ("data set" [Title/Abstract] OR ("data element"[Title/Abstract]) AND ((2010:2020[pdat]) AND (english[Filter]))
Scopus	(TITLE (zoonotic) OR TITLE (zoonosis) OR TITLE (zoonoses) AND TITLE-ABS-KEY (surveillance AND system) OR TITLE-ABS-KEY (information AND system) OR TITLE-ABS-KEY (registry AND system) AND TITLE-ABS-KEY (data AND field) OR TITLE-ABS-KEY (data AND element) OR TITLE-ABS-KEY (data AND set) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010)) AND (LIMIT-TO (LANGUAGE, "English"))
WOS	TITLE: (zoonotic) OR TITLE: (zoonosis) OR TITLE: (zoonoses) AND TOPIC: (surveillance system) OR TOPIC: (information system) OR TOPIC: (registry system) AND TOPIC: (data field) OR TOPIC: (data set) OR TOPIC: (data element). Refined by: Refined by: LANGUAGES: (ENGLISH (AND Timespan: 2010–2020.
ProQuest	ti(zoonotic) OR ti(zoonosis) OR ti (zoonoses) AND ab (surveillance system) OR ab (information system) OR ab (registry system) AND ab (data field) OR ab (data set) OR ab (data element). Date: From 2010 to 2020; Language: English
Science direct	TITLE ("zoonotic" OR " zoonosis" OR zoonoses") AND TITLE-ABS-KEY ("surveillance system" OR ″ information system" OR ″ registry system") AND TITLE-ABS-KEY ("data field" OR ″ data element" OR ″ data set") AND English[lang], limited to 2010–2020.

coordinated and collaborative efforts are required by human and animal health-related organizations as well as their subdivisions for early detection of epidemics, setting up effective response actions, preventing further propagation of diseases or reducing loss of human life and economic burden. To prepare for and deal with large numbers of incoming reports and alerts from humans, animals and foodstuff for surveillance purposes, setting a well-established and integrated surveillance system is of great importance, which provides close collaboration among governing authorities to direct disease control and prevention efforts [12–15].

As stated by world health organization (WHO), an efficient surveillance system should be able to perform some functions such as identifying and informing health events, collecting and integrating relevant data, investigating and confirming cases or outbreaks, creating and analyzing routine reports, providing feedback to data providers, feed-forwarding and reporting data to macro-level health policymakers [16]. Since zoonoses affect both human and animal populations, it is presumed that their surveillance should, at least for some purposes, target both populations and integrate the collected data among them [3,17,18]. Moreover, given that human and animal health are closely interrelated and the costs of assembling new data are high, the integration and reuse of these routinely collected data might be useful for improving the surveillance of zoonoses [19,20]. This type of surveillance can be referred to as one health (OH) surveillance. The OH approach aims to provide collaboration and communication between multiple disciplines such as wildlife biologists, veterinarians, physicians, agriculturists, ecologists, microbiologists, epidemiologists and biomedical engineers to achieve optimal health for humans, animals and the environment [21,22]. The requirements and returns of multi-sectoral communication to resolve human and animal health qualms are obvious, but the traditional, social and economical variances among sectors still exist as significant barriers[23,24]. Moreover, challenges concerning tasks, data exchanging and confidentiality limitations still represent hurdles for well-organized and unconstrained teamwork. Furthermore, basic things like scientific vocabulary and descriptions have been created separately in each department over time, complicating communication and collaboration between the parties involved in the health of human beings, animals and the environment[24–26].

Currently, there is no interoperable surveillance system for implementing OH surveillance in Iran for integrating data from involved organizations [27]. Thus, with the widespread outbreak of zoonoses, especially the ongoing COVID-19 pandemic, establishing an integrated and interoperable surveillance system is more required to facilitate detection and track new cases, investigate causes and control outbreak of zoonoses diseases [28,29]. Scientific experience proves that developing a well-designed ZDSS holds a large share in controlling zoonosis and preventing devastating human outbreaks. In addition, it supports the strengthening of public health settings for coordination, management, monitoring and evaluation of zoonoses [30,31]. Likewise, the effectiveness of ZDSS depends on data and reports from wide scattered public health and clinical-related information systems as data input. Depending on the source and purpose of collecting zoonoses data, this data is stored in isolated databases from different human and animal organizations [32]. In this sense, a consistent minimum dataset (MDS) is one of the key steps in establishing a collaborative surveillance system across organizations to increase inter-sectional and scientific collaborations [33–36]. As stated by Kowal et al., MDS is an agreement set of data items used for uniform data collection [37]. Some studies have stressed the importance of MDS to implement national information systems and support data exchange across health information sectors [38,39]. Thus, the present study, first, aimed to develop zoonotic disease minimum datasets (ZD-MDS) as a basic step for implementing the ZDSS. Second, it presented an exchanging framework toward interoperability between zoonotic diseases information systems (ZDISs).

2. Material and Methods

This descriptive and cross-sectional study was conducted in three phases as follows:

2.1. Literature review

Firstly, we performed a systematic literature review to define the zoonoses potential data elements. In this phase, to retrieve full-text related articles up to October 21st, 2020, scientific databases such as PubMed, web of science (WOS), Science Direct, Scopus and ProQuest were reviewed through the English MeSH keywords: ["zoonotic" OR "zoonosis" OR "zoonoses"] AND ["surveillance system" OR "information system" OR "registry system"] AND ["data element" OR "data set" OR "data field"]. After setting the advanced search options (search formula) and applying inclusion and exclusion criteria (search filter or refine result), the titles and abstracts of the potentially relevant studies were identified. Letters, posters, conference papers, review studies, lectures, duplicated, non-English and articles published before 2010 were excluded. Details of the search strategy are shown in Table 1.

2.2. Delphi phases

All the scientific literature and databases related to zoonoses diseases were studied and the potential data items and their corresponding

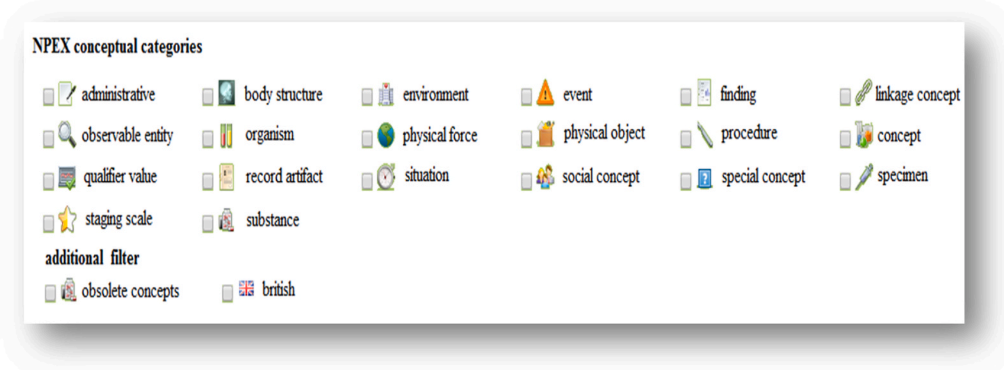

Fig. 1. NPEX online browser.

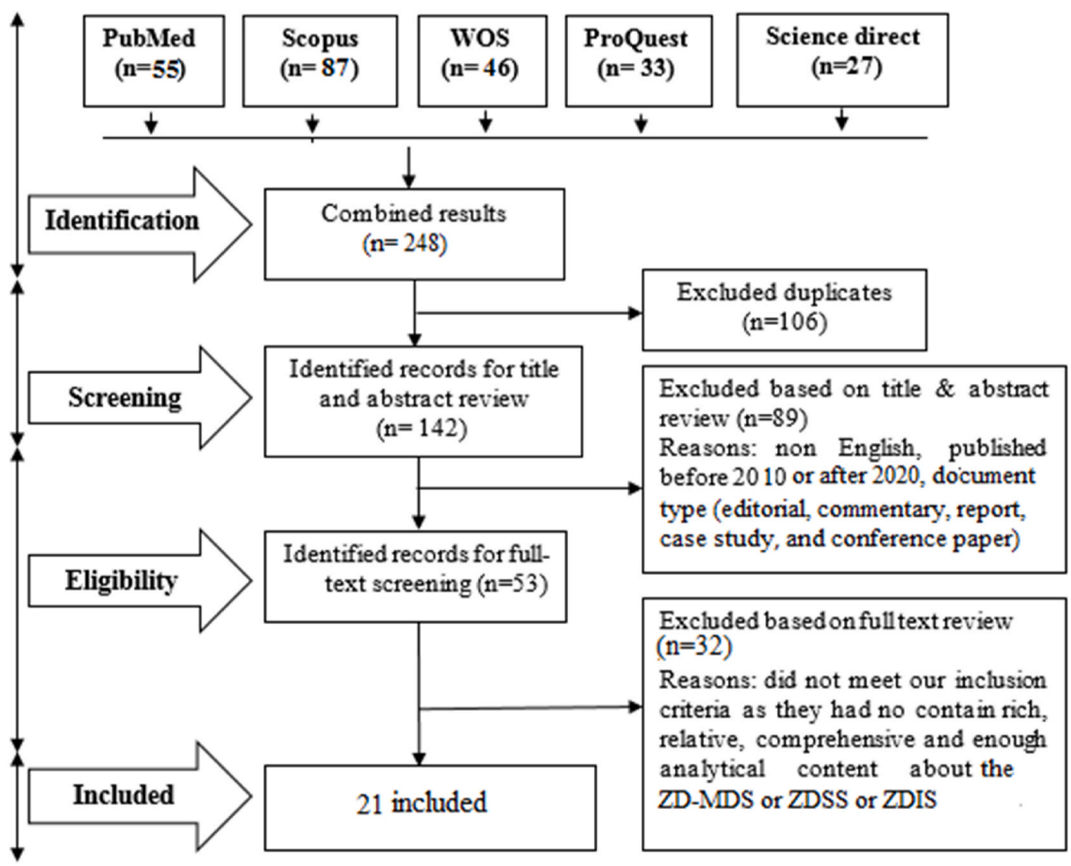

Fig. 2. PRISMA chart in the study selection process.

values were extracted. Then, a researcher-made questionnaire was designed using the potential data items with five columns in front of each data item. To determine the final ZD-MDS, an expert panel was considered, including 20 specialists working in Ilam and Abadan universities of medical sciences (as common areas of zoonotic diseases in Iran) with at least three years of work experience and research background in zoonotic diseases. The panel of experts included five parasitologists (three PhD- and two MSc-holders), five epidemiologists (four PhD- and one MSc-holders), five public health practitioners (one MSc- and four BSc-holders)and five infectious disease specialists. The median age of the 20 participants, of whom 13 were male and 7 were female, was 43 years old (range: 23–58 years old). Using a two-rounded Delphi technique, the participants were asked to score each item according to the importance perceived by them based on a five-point Likert scale ranging from one (very low importance) to five (very high importance) [1]. At the end of each section, a blank row was considered for adding necessary data elements by experts. The content validity of the questionnaire was evaluated by a panel of experts, including two infectious

Table 2
Administrative section of ZD-MDS.

Data classes/fields	Content definition	Field format	Content	SNOMED-CT category	SNOMED-CT codes
Basic data					
Patient name& surname	alphabetical	string	patient name	observable entity	371484003
Age	*Infant: <1 year *child:1–5 year *Teenage: 5–17 year *young: 17–34 year *Middle age: 34–64 year *aged: >65 year	Categorical	middle-age: 54y	clinical finding	28288005
Date of birth	yyyy/mm/dd	integer	1966/12/05	observable entity	184099003
Gender	*Male: 1 * female: 0	binary	1	clinical finding	703117000
Marital status	*single *married *widow	categorical	married	clinical finding	87915002
Ethnicity	*Iranian * non –Iranian	categorical	Iranian/persia	qualifier value	297553001
Religion	*Islam *Christianity *Jewish * Zoroastrian *other specified	categorical	Islam/shia	social context	28010004
Employment status	*employed * unemployed	categorical	employed	clinical finding	224363007
Occupation	***High-risk jobs:** jobs in direct contact with animals (poulterer, livestock breeder, slaughterhouse, livestock market, veterinarians, and veterinary staff, wildlife officers, zookeepers, animal careers, and pet owners) ***Medium risk jobs:** jobs in indirect contact with animals (farmer, meat-processing workers, environmentalists, shooters) ***Low-risk jobs:** jobs without contact with animals	categorical	livestock farmer	social concept	52060003
Average monthly income	*Low income: x < 25000000rial *Medium income: 25000000<x < 70000000rial * High income: x > 70000000rial	categorical	low income	clinical finding	424860001
Literacy rate	*l-0: illiterate *l-1: functional literacy *l-2: basic literacy *l-3: proficient literacy * l-4: advanced literacy	categorical	illiterate	clinical finding	707843000
Type of residence	*urban *rural *other specified	categorical	rural	environments and geographical locations	224804009
Type of ownership of housing	* owner * tenant * homeless	categorical	Owner	clinical finding	160943002
Food habit	***Unhealthy:** raw foodism, fast food, or highly processed foods. * **Healthy:** pasteurized, cooked (boiled, streamed) * Unknown	categorical	healthy eating	qualifier values	723881000000101
Phone number	+98 xxx-xxx-xxxx	integer	+98 xxx-xxx-xxxx	observable entity	824551000000105
ID numbers					
Patient identifier	Numbers range from two to ten digits with two separator dashes	integer	xxx-xxxxxx-x	observable entity	422549004
Visit number	A four to eight digits with dash	integer	xxx-xx	observable entity	722248002
Provider ID	Numbers range from two to eight digits without the dash	integer	xxxxx	observable entity	713578002
Record number	Six digits with two separator dashes	integer	xx-xx-xx	observable entity	398225001
Healthcare center ID	Numbers range from three to six digit	integer	hospital ref. no: xxxx	observable entity	185975009
Payment ID	A four to six digits with separator dash	integer	xx/xxxx	observable entity	716931000000107
Report ID	six digits with two separator dashes	integer	xxx-x-xx	observable entity	439272007
Report Date	yyyy/mm/dd	date	2020/03/16	observable entity	399651003
Geographical (spatial) data					
Place of birth	country, province, district, city/village	string	Iran/Tehran	clinical finding	315446000
Current residence address	City/village, street, alley, house no.	string	home address	observable entity	184097001
Postal/Zip code	ten digits with a separator dash	integer	xxxxx-xxxxx	observable entity	184102003
Travel destination	district/region	string	not applicable	qualifier value	385432009
Location of exposure	district/region	string	agricultural site	environments and geographical locations	272504001
Healthcare center location	city/village, street, alley	string	Hospital address	observable entity	308916002
Environmental/wildlife situation data					
Cultivation rate	*Fully-agricultural *semi-agricultural *non-agricultural *other specified	categorical	agricultural	environment/ location	272504001
Role of wildlife	*High (rural, nomads) *Medium (semi-rural) *Low (urbanist)	categorical	rural environment	environment/ location	224804009
Livestock population	*Low: 100> *medium: 100-1000 *High:1000–10000 *very high: 10000<	categorical	environment contains uncontrolled (very high) livestock	clinical finding	424093009
Farming/husbandry approaches	* Traditional (non-technological) *semi-technological * Fully-technological	categorical	traditional	qualifier value	263901007
Wildlife biodiversity (the number of wild bio species)	*Low: 10> *medium: 10-100 *High:100–1000 *very high: 1000<	categorical	medium bio diversity	special concept	26604007

(*continued on next page*)

Table 2 (*continued*)

Data classes/fields	Content definition	Field format	Content	SNOMED-CT category	SNOMED-CT codes
The environment	⁎ desert ⁎ rangelands ⁎rainy forest ⁎ plain ⁎cold and mountainous ⁎other specified	categorical	plain district	environments and geographical locations	308916002
Environmental health approaches	⁎Low: traditional ⁎Medium: primary or basically ⁎Desirable: scientific and engineered	categorical	primary environmental health measures	special concept	311224000
Climate	⁎temperate ⁎tropical ⁎ hot &wet ⁎ polar ⁎ hot&dry ⁎ other specified	categorical	hot &wet	events	217593006
Climate change	⁎ yes ⁎ no	binary	yes	qualifier value	724471000000104

diseases specialists, two parasitologists, three medical informatics and three epidemiologists. Test-retest reliability (with a 10-day interval) was performed to determine the reliability of the questionnaire. The collected data was analyzed using SPSS version 19 and Spearman's rank correlation coefficient of 84% was achieved. Through a Delphi technique in two rounds, deciding on included data items was based on the agreement level. In this way, data items with less than 50% agreement (the average score of less than 2.5) were excluded, first, and those with more than 75% agreement (the average score of above 3.75) were included in the preliminary rounds. Data elements were surveyed with 50%–75% agreement (the average score between 2.5 and 3.75) in the second round and 75% agreement on one issue was considered the final data element.

2.3. Sematic and syntax validation

In our study, after designing the MDS of zoonotic diseases, its content was standardized through comprehensive standard and integrated codes. NPEX browser software was used to link the contents to the systematized nomenclature of medicine-clinical terminology (SNOMED-CT) structure. After content standardization, the structure standardization was done. For this purpose, a clinical document architecture (CDA) format, which is specifically the exchange of clinical documents, was used. In addition, extensible markup language (XML) codes were used for labeling.

The data element content was standardized using SNOMED-CT browser, entitled NPEX online browser (https://snomedbrowser.com/). SNOMED-CT was used, as the most comprehensive, precise and structured clinical terminology for electronic healthcare information exchange (HIE) [40,41]. The SNOMED-CT NPEX conceptual categories were classified into 20 classes including administrative, observable entity, qualifier value, staging scale, body structure, organism, record artifact, substance, environment, physical force, situation, event, physical object, social concept, finding, procedure, unique concept, linkage concept, product, specimen and additional filter (Fig. 1).

This process was visualized through Mind maple Lite 1.71 application software as a graphic user interface, representing thesaurus mapping across multiple medical terminologies. Then, the integrated SNOMED-CT codes were structured into an approved messaging standard framework to provide syntactic interoperability. The health level seven-clinical document architecture (HL7-CDA) standard was proposed as an optimal and consistent structure for the zoonoses surveillance system. Accordingly, integrated reference codes were structured into HL7-CDA standard framework to provide syntactic coordination.

3. Results

3.1. Identifying the proposed data field

The present systematic review was reported according to the preferred reporting items for systematic reviews and meta-analysis (PRISMA) standard which describes the identification, screening, eligibility and inclusion criteria of the articles falling under the scope of the review [42].

The initial search in the selected scientific database yielded 248 citations, 142 of which remained after omitting the duplicates and 53 of which remained after removing non-English, those published before 2010 or after 2020 and the document type ones (editorial, commentary, report, case study and conference paper). Twenty-one articles [17, 27–46] were identified as eligible studies to meet our criteria in the last screening phase. Full-text articles were obtained for the detailed evaluation and eligible studies were included in the systematic review (Fig. 2).

The designed ZD-MDS structure in this study included data categories, classes and fields. After the literature review, the proposed dataset was divided into 11 classes including basic data [43–56], ID numbers [46,48,52,57–59], geospatial data [43,46,50,56–58,60,61], environmental data [27,47,53,54,58,59], disease parameters [46–51, 54,55,58,59,61,62], clinical risk factors [43,46,47,49,51,57,61,62], physical examination [43,45,48,50,52,53,62], exposure data [43,44,50, 51,53–55,57], laboratory data [27,44,45,47,50,51,53,54,60,62], treatment plan [27,43,45,48,51–53,55,57,61] and discharge information [46,49,52,53,57]. These classes contained 19,14, 6, 9, 21, 14, 6, 9, 10, 13 and 7 data items, respectively (n = 128).

3.2. identifying the final data field

After the first round of Delphi, from among 128 proposed data fields, 78 fields were finalized, 36 fields entered the second round and 14 fields were excluded from the study. Finally, out of 36 data fields in the second round, 19 fields were excluded. While the final ZD-MDS comprised two sections, with 11 data classes and 95 data items, the administrative section consisted of four classes and 38 data items. The clinical section contained seven classes and 57 data items (Tables 2 and 3).

3.3. Content and structure validation

All the scattered terms were mapped to integrated codes in the SNOMED-CT reference nomenclature system using NPEx online browser. The SNOMED-CT conceptual framework for the total of 95 data fields in the proposed ZD-MDS was classified into 20 conceptual categories, including observable entity [23], qualifier value [15], organism [1], substance [4], environments and geographical location [3], situation [2], events [2], social concept [2], clinical finding [35], procedure [3], unique concept(3), linkage concept(1) and specimen [1]. All the mapping routes were displayed through MindMaple software (Fig. 3).

After content standardization by integrating SNOMED-CT codes, the zoonoses report structure was designed in three layers: 1-free text CDA templates (first CDA level), 2- XML hierarchical (second CDA level) and XML tags (syntax) (third CDA level).

3.3.1. Free text CDA

The XML-based CDA framework of the HL7-V3 messaging standard was leveraged to standardize clinical documents in the web environment. HL7-CDA allows different healthcare organizations for effective information sharing by standardizing the structure (syntax) and content

Table 3
Clinical section of ZD-MDS.

Data classes/fields	Content definition	Field format	Content	SNOMED-CT category	SNOMED-CT codes
Disease parameters					
Admission cause	free text	string	skin simple lesion	qualifier value	264920001
Admission date	yyyy/mm/dd	date	2020/03/12	observable entity	399423000
Disease manifestation	*Skin sores *stuffy nose, runny nose, and nosebleeds *Swallowing difficulty *itching *fever *Difficulties breathing *encephalitis *rashes *Hemorrhagic fevers *arthralgia *other specified	categorical	itching of lesion of the skin skin score	clinical finding	445329008
Final diagnosis	free text	string	zoonotic form of cutaneous leishmaniasis	clinical finding	15207003
Date of diagnosis	yyyy/mm/dd	integer	2020/03/11	observable entity	432213005
Symptom onset date	yyyy/mm/dd	integer	2020/03/08	observable entity	520191000000103
The time between exposure to symptom onset	day: d week: w month: m year: y	numerical	2w	qualifier value	307474000
The time between symptom onset to diagnosis	day: d week: w month: m year: y	numerical	3d	qualifier value	307474000
The time between symptom onset to treatment	day: d week: w month: m year: y	numerical	1w	qualifier value	307474000
Disease certainty level	*final *suspicious *probable	categorical	on primary examination-suspicious	clinical finding	163614007
Disease severity	*mild *moderate *severe *critical	Categorical	moderate condition	clinical finding	67106002
Disease status	*active *in active *recovered	Categorical	active	clinical finding	110278006
Disease category	*visceral *cutaneous	Categorical	cutaneous leishmaniasis	clinical finding	240637006
Disease complications	free text	String	scar of skin	clinical finding	70582006
Length of stay (if hospitalized)	day: d, week: w, month: m, year: y	Numerical	2d	clinical finding	169628008
Zoonosis risk factors					
Elderly	* yes * no	binary	no	clinical finding	248227006
Poor immune function	* yes * no	binary	no	clinical finding	248227006
Recent travel	* yes * no	binary	does not travel	clinical finding	300616000
Presence of comorbidity (any disease on active therapy)	* yes * no	binary	yes	clinical finding	52101004
Comorbidity name (if yes)	free text	string	pre-diabetes	clinical finding	858301000000107
Addiction	* yes * no	string	no	clinical finding	248227006
Mental state	free text	string	stress	clinical finding	73595000
Pregnancy	* yes * no *sexual incompatibility	categorical	sexual incompatibility	clinical finding	91525005
Disease history	* yes * no	binary	no past history of (contextual qualifier)	qualifier value	138009
Disease history name (if yes)	free text	string	no history of (contextual qualifier)	qualifier value	138009
Previous surgery	* yes * no	binary	no past history of (contextual qualifier)	qualifier value	138009
Previous surgery name (if yes)	free text	string	no history of (contextual qualifier)	qualifier value	138009
Physical examination					
Body temperature	*Hypothermia: 35< *border line low: 35–36.1 *Normal range: 36.1–37.2 *borderline high: 37.2–39 *Pyrexia: 39>	categorical	body temperature above reference range	clinical finding	50177009
Respiratory rate (per minute)	*Bradypnea: 12< breath per/min *Normal range: 12–20 breath per/min *Tachypnea: 20> breath per/min	categorical	respiratory rate normal	clinical finding	20716004
Heart rate (beats/per minute)	*Bradycardia: 60 < beat per/min *Normal range: 60–100 beat per/min *Tachycardia: 100> beat per/min	categorical	normal heart rate	clinical finding	76863003

(continued on next page)

Table 3 (*continued*)

Data classes/fields	Content definition	Field format	Content	SNOMED-CT category	SNOMED-CT codes
Body Mass Index (BMI)	*Underweight: 18.5 > *normal: 18.5–24.9 *Overweight: 25.0–29.9 *obese: 30<	categorical	normal body mass index	clinical finding	35425004
Blood pressure [mmHg]	*Low bp: >90/>60 mmhg *Normal bp: 90–120/60–80 mmhg *Elevated bp: 120–129/80 mmhg *High bp (stage1): 130–139/80–89 mmhg *High bp (stage2): 140≤/90≤ mmhg *Hypertensive crisis: 180</120<	categorical	normal blood pressure	clinical findings	2004005
Lung auscultation (sounds)	*normal *rales *rhonchi *wheezing *crackles *vesicular *other specified	categorical	normal auscultation	clinical findings	129436005
Exposure data					
Exposure history	* yes * no	binary	history of exposure to risk factor	situation	705133000
Transmission route	*direct/close contact *air borne/inhalation *contaminated lands or water *oral-fecal route *vector borne *tick-borne *arthropods-borne *latent infections *other specified	categorical	vector-borne transmission	qualifier value	418427004
Type of pathogen	*bacteria *virus *rickettsia *helminthic *ectoparasites *parasite (protozoal) *nematode *fungus *infectious protein virus like particle (prion) *other specified	categorical	parasite (protozoa)	special concept	46770001
host carrier (reservoir)	*livestock *pets *wild animals *insects *reptile *birds *other specified *unspecified	categorical	insect carrier	organism	106763003
Cause of exposure	* occupational * non-occupational *Other specified *unspecified	string	occupational hazard	events	16090731000119102
Activity on exposure	*work *leisure *Other specified *unspecified	string	work-related activity	observable entity	80638004
Date of exposure	yyyy/mm/dd	integer	integer	linkage concept	410671006
Number of exposures	* frequently * sometimes * rarely *other specified *unspecified	string	sometimes	observable entity	228863009
Laboratory data					
Laboratory test	free text	string	direct smear	procedure	104221004
Test time	yyyy/mm/dd	integer	xx:xx:xx	observable entity	252127002
Specimen type (& site if appropriate)	free text	string	skin lesion sample	specimen	309068002
Sample ID	xx-xx	numerical	sample id no.	observable entity	719051000000105
Final LAB diagnosis	free text	string	positive skin lesion sampling test	clinical findings	309068002
Biological sample	feces mesenteric lymph nodes swab blood				
Treatment plan					
Type of treatment received	*medical/surgical *Supportive *Complementary *Other specified	categorical	complementary therapy	procedure	225423004
Procedure name	free text	string	cryotherapy to skin lesion	procedure	302396003
Prescription history	* yes * no	binary	History of prescription	situation	394824001
Previous treatment for the current problem (first choice)	free text	string	rifampicin gel	substance	416821000
Drug category	*Chemical medicine *Herbal medicine *Combination drug	categorical	chemical	substance	441900009
The second choice drug used	free text	string	meglumine antimoniate	substance	714533009
Other drugs currently used	free text	string	insulin lispro	substance	372756006
Discharge information					
Discharge status	*Referred for specialized services *post-discharge follow-up *Full recovery *deceased	categorical	post-discharge follow-up	clinical finding	406151001
The underlying cause of death (if deceased)	*Related to zoonotic disease *Related to zoonotic disease *Not applicable * Unknown	categorical	not applicable	qualifier value	385432009
Discharge date	yyyy/mm/dd	date	2020/03/15	observable entity	442864001

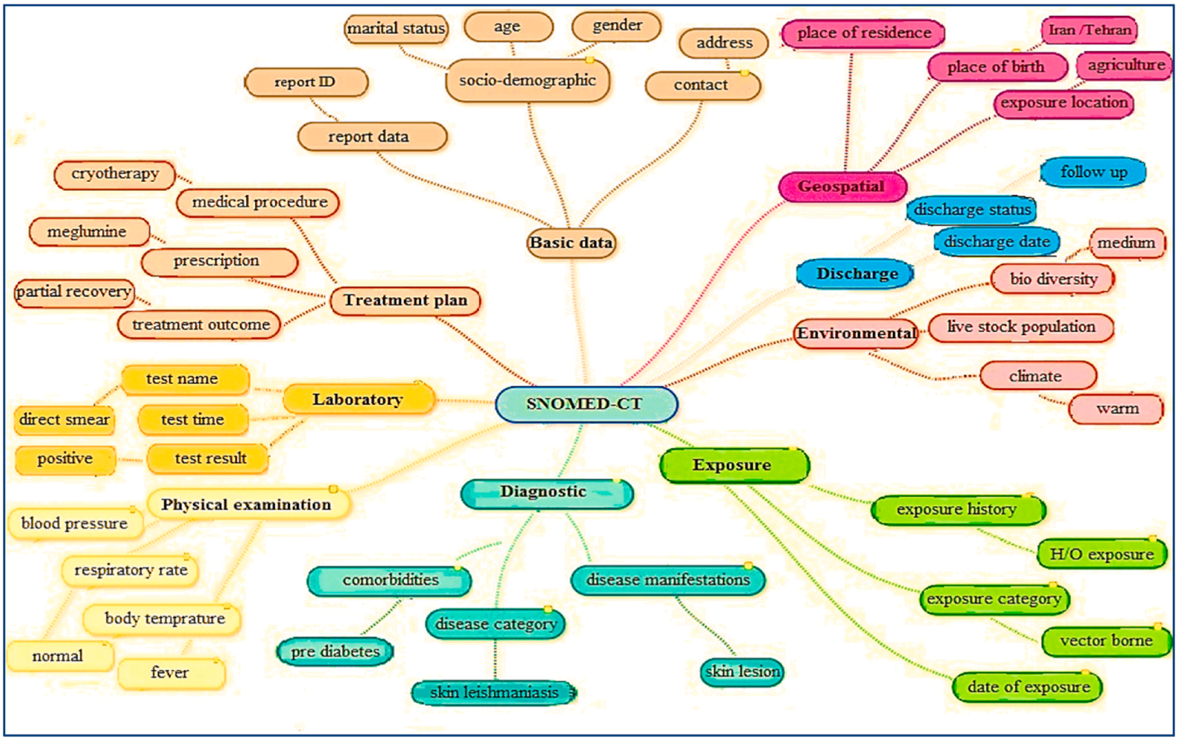

Fig. 3. Mapping routes.

(semantic) of massages. CDA uses a logical structure for data classification and arrangement according to a standardized and predefined structure. In the present CDA structure (Fig. 4), the data field related to identifying entities such as general data, identifier and report data was pasted into the document heading. The body contained detailed information about geospatial and environmental, diagnostic, treatment plan, exposure, history and discharge information.

3.3.2. XML tree

The XML standard is used to define structuring, validation as well as organization and standardize documents in the network-compatible format for transmission. It creates a structured data format for electronic data exchange over the Internet. An XML hierarchy is a tree-like structure where elements are arranged by parent/child or containment relationships (contains/contained). Each XML document has a "root" or "parent" which "contains" all the other elements (child and sub-class). In our XML structure, the ZDSS is the root node, which contains three classes: basic, geospatial and clinical data classes with 12 sub-class. Fig. 5 displays the hierarchical structure of the XML with leaf nodes (sub-classes) for the nonclinical category.

3.3.3. XML syntax

The tags are the important features of an XML document that structure, label and organize the message structure. They provide data for XML by defining each data section, performing accurate organization and labeling data elements for transmission in the web environment. In the present study, the XML tags defined the scope of elements in the ZDSS document (see Fig. 6).

4. Discussion

In this study, first, the ZD-MDS was presented, including the required data items for unified recording and reporting zoonoses surveillance data. The proposed ZD-MDS provided human, animal, food and agricultural sectors and their stockholders with a comprehensive and consensus dataset for unified reporting zoonoses data across various settings and software systems. Second, by leveraging HL7-CDA standard and terminology mapping, the ZD-MDS would become a communication protocol towards integrating isolated zoonoses-related databases and information systems.

Ammon et al. (2010) designed the European surveillance system (TESSy) that reported the cases based on three human, animal and food data classes. They suggested an XML-based zoonoses reporting application substitute for paper reporting until the fully automatic and interoperable transmission is in place [63]. Scotch et al. (2013) proposed a ZDSS framework in four general, geographical, clinical/para-clinical and environmental/wildlife data classes. Besides, they designed a semantic web approach to promoting online resources and concepts [64]. Wendt et al. (2015) developed ZD-MDS in two clinical and nonclinical categories; providing customized data and messaging standards was a key prerequisite for OH ZDSS establishment [55]. Das et al. (2019) developed a web-based zoonotic registry template based on the HL7 standard with four demographical, exposure, environmental and diagnostic testing sections [65]. Omazic (2019) developed a standardized template for reporting zoonotic infectious diseases in three basic, clinical and animal/food data categories. In that study, the interoperability requirements were not met [66]. Muligan et al. (2019) developed the zoonoses data model in six prevalence, antimicrobial resistance, food-borne outbreak, animal population and disease status classes. They used the EFSA's standard terminology and XML structural standard for semantic and syntax interoperability, respectively [67]. Shapiro (2021) presented a framework for content normalization of zoonotic data for information exchange on the Internet. Accordingly in the present study, after designing MDS as a basic function, all the interoperability requirements were met through semantic (data mapping) and syntax (CDA based XML) standardization [68].

Well-established and standardized information systems for zoonoses reporting would improve interoperability, reusability, integrity, reliability and quality data criteria, thus eliminating unnecessary redundancies and reporting burden on public health agencies. Interoperable ZDSS can thus help improve the standardization of scientific research to successfully combat the diseases pandemic [29,46,

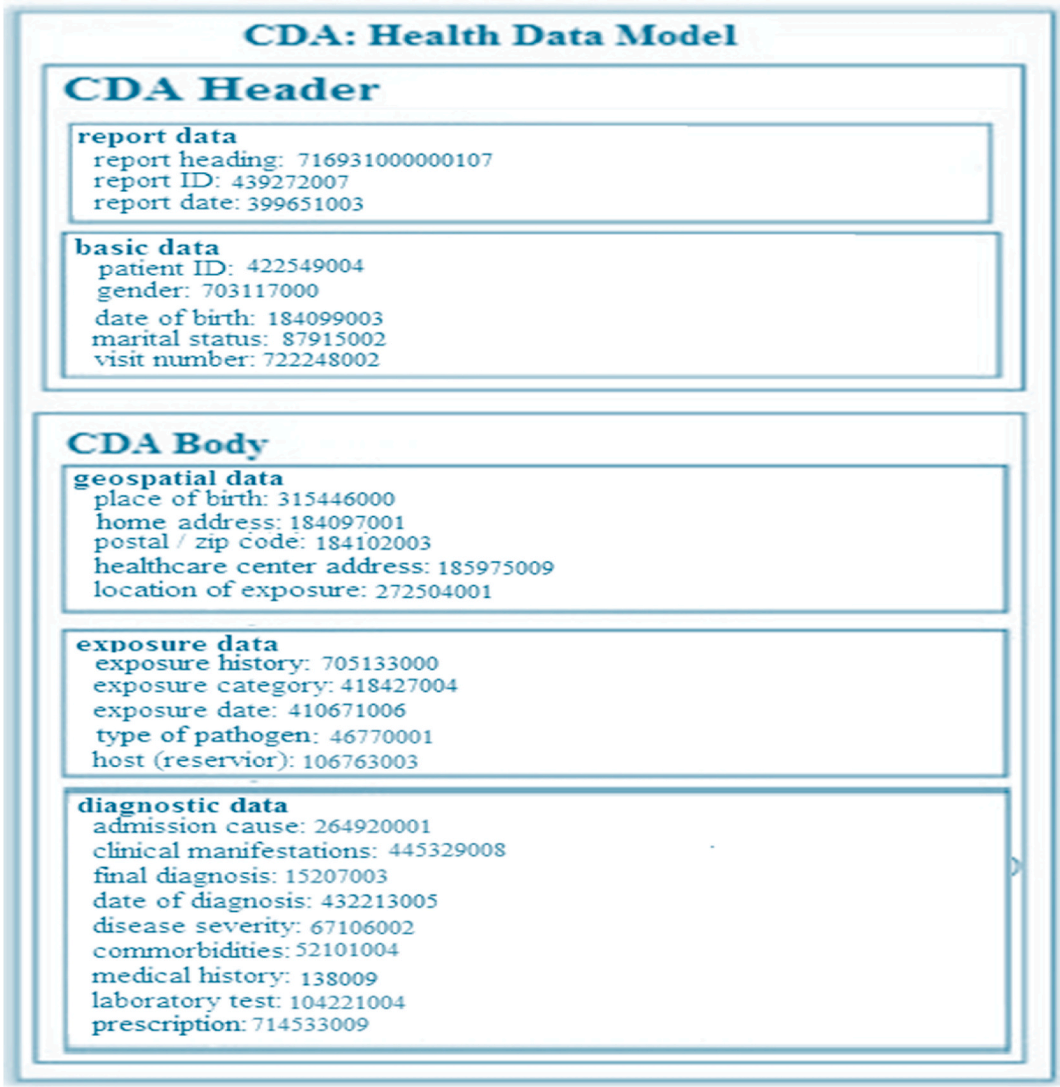

Fig. 4. Free text CDA structure.

52]. Our study used the reference terminology tools to normalize zoonoses reporting. To this end, all the data elements were mapped into their SNOMED-CT unique codes; then, according to the HL7-CDA standard, the zoonoses communication protocol was developed. HL7-CDA is a simplified and optimal human-computer comprehensible format, playing a crucial role in exchanging a wide variety of clinical data. Besides, this standard uses an XML template that provides consistent public health data exchange by structuring the message framework amid various systems. The developed zoonotic diseases reporting communication protocol in the present study can be used as a standard tool for developing an interoperable ZDSS. This communication protocol can enable interoperability among public health and veterinary information systems that populate the ZDSS. The main output of the proposed communication protocol supported partnerships between numerous healthcare providers and public health agencies for patient care management, epidemiological research and public health purposes. The most important limitation of the present study was that it only focused on the information management aspect of the ZDSS. Still, the technical and legal aspects remained to be resolved. However, the interoperability level considered in this study went beyond the basic level (machine--portable data) and reached high interoperability (machine-interpretable data). Furthermore, the ZD-MDS might need to be assessed from the standpoints of a larger assembly of medical and public health experts to be valid nationwide.

5. Conclusion

Proper and effective surveillance of zoonotic diseases demands timely and useful evidence for guiding fully informed decisions to further propagate diseases by taking early preparedness and preventive actions. The proposed template in our study can help healthcare providers, public health experts, healthcare authorities and researchers with an inclusive and coordinated dataset in terms of reporting, exchanging and analyzing zoonoses data across organizations and software systems, as major purposes for OH surveillance, in Iran. We recommend developing conceptual models of surveillance systems and conducting a pilot study including a further Delphi stage before refining some data categories.

Ethical approval

This article is extracted from a research project supported by the Abadan University of Medical Sciences (Ethical code: IR. ABADANUMS. REC.1399.135). we appreciate the research deputy of the Abadan University of Medical Sciences who sponsored this project financially.

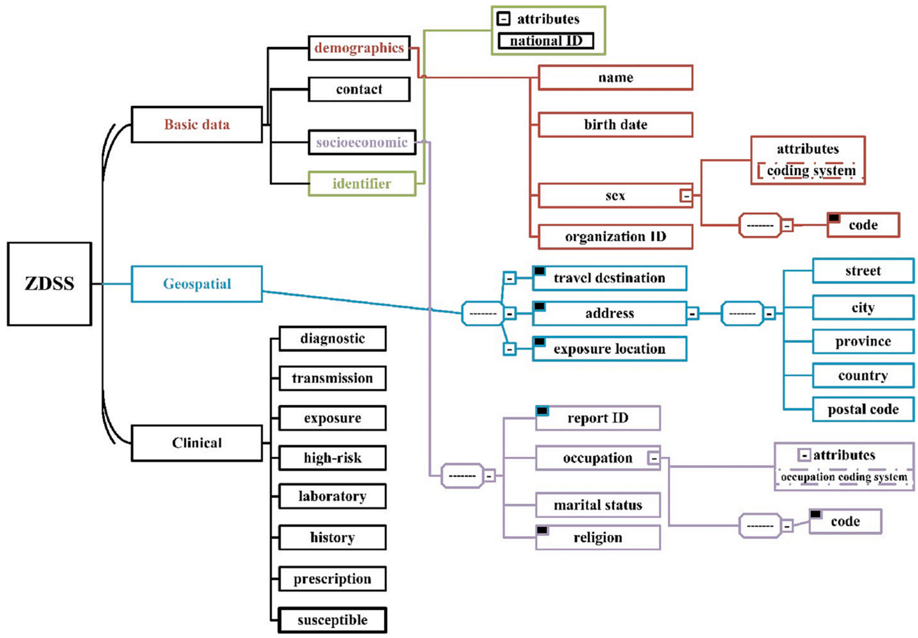

Fig. 5. XML hierarchical.

```
{
  resource type:  "zoonotic disease surveillance system"
  purpose:  "interoperability"
 - category:  "administrative"
   < class:  "demographic"
   < code system:  "SNOMED-CT"
     < contains:  [= /observable entity
       - {
         < system: "NPEX online browser"
           < code:  "302147001"
           < person firstname:  ="nabi"
           <      middle name: xsi:nil= "true" />
           <      last name:  > "asadi" < / last name>
             < code:  "371484003"
     < contains:  [= /clinical findings
       - {
          < code:  "302147001"
          < gender: "< male >"
          < code:  "703117000"

    < class:  "contact"

     - address:
     <street name>
     <city> Tehran </city>
     <post - code> 45147-69311 </"post_ code">
      < code: "184097001"
```

Fig. 6. XML tags.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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