A Conceptual Double Scenario Model for Predicting Medical Service Needs in the International Disaster Relief Action

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ABSTRACT

Man-made and natural disasters have affected people worldwide. Mass casualty incidents would create a surge in demand for medical services. **Medical service needs** are the basis of medical strategic readiness plan. In recent years, international actions have been criticized for being ill-adapted to dominating health needs of the affected region. The "**Scenario-Response**" modeling is an important method in disaster prediction. This research established **a medical service needs conceptual scenario model** with two different levels of ambition: a disaster scenario, in which casualty figure, composition of injuries are constrained by the types of the disaster as well as the degree of the damage, and a country scenario, in which the healthcare needs are constrained by the health coverage and the health condition of local people. In this research, Armed conflicts in Yemen and Syria Arab Republic was selected as research target where the model is applied to conduct the relevant analysis. The results proves that the outcome earned by using this model could fit the reality to a great extent..

Keywords

Disaster Relief; Medical Service Needs; Scenario Model.

INTRODUCTION

Over the past years, man-made and natural disasters have affected large numbers of people worldwide. Some of the disasters were sudden-onset disasters (SOD), such as earthquake outbreaks and terrorism attacks, while the others would exist for a long period of time, such as humanitarian crisis or armed conflicts.(Leaning and Guha-Sapir, 2013) Once these disasters happen, mass casualty incidents will create a surge in demand for emergency medical services. In some countries, especially low and middle income countries, international actions are needed. (Reinhardt et al., 2011)

The basis of international action is medical resources preparedness, such as staffing, requisite equipment, and needed medical supplies. (Guha-Sapir, 1991)Medical resource preparedness is based on determining the likely composition of injury or patient streams during the action. (Zouris et al., 2001) "Scenario-Response" model is the main method for disaster relief study. This model has been applied in making Readiness Strategic Plan, simulating exercising, predicting and early warning and so on. (Wei et al., 2017) Some medical relief "Scenario-Response" models focus on establishing the disaster scenario which could determine the likely amount and composition of injury or patient stream after disaster outbursts. Then the medical resources readiness plan could be made based on them. (Zouris et al., 2001) Other scenario models are optimization models which focus on optimizing the medical evacuation decision making, the priority for receiving care, the medical resource effective allocating, etc.(M. and K., 2017; PP. et al., 2016) All these models tend to focus on providing life-saving trauma care in the early disaster relief period.

But in recent years, foreign medical rescue teams deployed to sudden-onset disasters (SOD) have been found to arrive too late to provide life-saving trauma care. They have also been criticized for over focusing on trauma care and for being ill-adapted to dominating health needs of the affected region(Gerdin et al. 2013). During the disasters, local health services may be disrupted so that international help is necessary and urgent needed, not only in dealing with the effects of the disaster but also to maintain routine health facilities for unrelated conditions (Motamedi et al., 2012; Reinhardt et al., 2011).In some experience summary articles, the influences of the local health service coverage, the local people health condition, the health condition of children, and professional health service for children and other special population are instantly mentioned. For example, some articles focus on the children and maternal in the armed conflicting region. (Zeid, 2015)Who are more vulnerable and easy to be injured when facing the disaster. (Yonekura et al., 2013) Without local professional service to specific person, the humanize crisis is more likely to occur. Some other articles also evidenced that people with chronic diseases (PCDs) are easy to get hurt in the disaster.(Chan and Sondorp, 2007) Some research mentioned the neglect of PCDs in the disaster relief. The lack of medicine for PCDs in the relief results in non-sustainable treatment for PCDs which could lead to series of consequences even life loss. (Miller and Arquilla, 2008))

So when we consider establishing the Scenario model for international medical relief, we should not only take emergent medical needs into consideration, but the local health service coverage and population health condition also.

BACKGROUND

Up to recently, no research is found to establish a model consider both the disaster characteristics and the characteristics of local health coverage and the basic health condition of local population.

The main concern of World Health Organization (WHO) is the potential risk of pandemic after the disaster, even that was unconfirmed yet. WHO also published a general guideline for international medical rescue team to follow when executing an international action. But according to some research, this guideline was not fully followed due to several reasons. One reason is that this guideline is not associated with the local reality. (Gowing et al., 2017)

Since 2010, six "Mission Harmony" humanism medical assistant actions have been executed world-wide based on the "Ark Peace" hospital-ship, PLA, China. Medical resource preparedness plan have been made before setting out according to the composition of patients offered by the local health department. But when the hospital-ship arrived the destination, the situation is different to what had been estimated. The patients were mainly children, women and the elders and the composition of disease is different from what is offered. Some of the medical resources, such as medicines for children and some sort of acesodyne were used up while the intravenous (IV) fluids and some sort of antibiotic were wasted. (Sun et al., 2016)

In order to enhance the efficiency and reasonability of medical resource preparedness during international medical relief action, more factors related to local health service and health condition should be taken into concern when establishing the scenario model.

METHODS

We modeled a scenario model with two different levels of ambition: a disaster scenario, in which mortality, casualty figure, composition of injuries are constrained by the types of the disaster as well as the degree of the damage, and a country scenario, in which the healthcare needs are constrained by the health coverage, the health condition, the communicable disease and non-communicable disease contribution and the service availability towards the special population such as maternal and children. We estimated the associated medical needs are both effected by the two scenarios.

The outcome of this model is the medical service needs which are the basis of medical resource preparedness plan. The model could provide the likely composition of injury or patients which determines the composition of staffing, requisite equipment, medicine and other needed medical supplies.

An abridged general view of the model is shown in Figure1. The characteristic indexes of the medical service needs are approximate injury or patient amount , composition of injury or disease condition and composition of injury or disease type. The disaster-level model is related to the characteristic factors of the disaster such as the type and degree of the disaster, the area struck by the disaster, the time when the disaster happened, etc. This model have a great effect on the medical needs greatly at the first period of time (T1) during which most survivors are discovered.

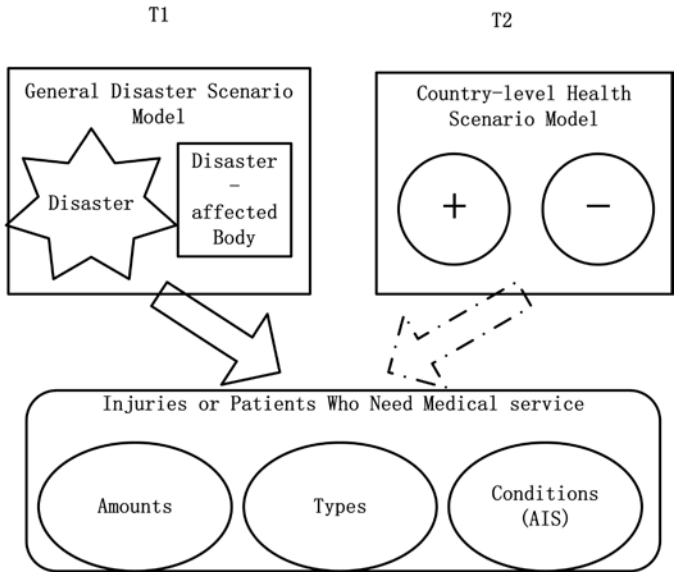

Figure 1. Abridged General View of the Double-level Scenario Model

But with the expansion of time, especially close to the end of golden rescue time, the country-level model have a gradually increasing influence on the medical needs in the second period of disaster relief time (T2). (Lulu et al., 2012) The country-level model is related to the characteristic factors of the country's health condition and health service coverage.

Further description of the double-level scenario model are as follows.

Level 1-- General Disaster Level Scenario Model for Medical Service Needs Prediction

There are lots of researches on the models of emergent medical service needs constrained by the disaster characteristics. But these researches didn't reach a common consensus on the definite model. But reviewing these researches, the relationship between the disaster characteristic factors and the medical service needs are certain. The indexes to describe the emergent medical service needs have high correlation with the disaster characteristic factors such as its time, area, type, degree and the fragility of disaster-affected body or region. Generally speaking, if the disaster hit wide range of area and took place at a severe degree, large amount of injury and more severe hurt injuries would occur. If the disaster outburst during night, injury amount would be larger. If the region hit by the disaster had high fragility such as poor quality of construction, disadvantage landforms and so on, the injury amount and severe hurt injuries would also increase. Certain types of injury would increase in certain disasters, for example, crush injuries would increase in earthquake, burn injuries and airway damage would increase in fire hazards, explosive injury and bullet wounds would increase in the armed conflicts, etc.

Based on these researches, we established a conceptual model of disaster level medical service needs. We use Injury Amount (IA)、Composition of Injury Condition (CIC) and Composition of Injury Type (CIT) as outcome indexes to describe the medical service needs. The model's income indexes are Disaster Type(DTy), Disaster-affected-area Fragility (DF), Disaster-affected Population (DP)、Disaster Degree (DD)、Disaster Time (DTi). The abridged general view of the model is shown in Figure2.

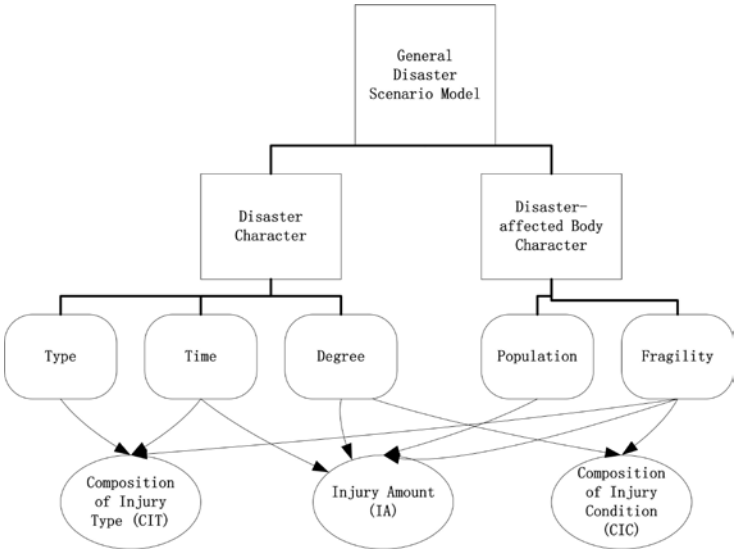

Figure 2. Abridged general view of the disaster level model

The mathematical expression of the conceptual model is as follow.

{IA, CIC, CIT}-f{DTy, DC, DP, DD, DTi}

This expression could decomposed into 3 sub-expressions.

(1) IA=f'(DP, DD, DF, DTi) (when DTi≦7, value DTi the actual day number; when DTi>7, value DTi =7)

In this sub-expression, DP is the base number of the injury amount which has positive correlation with DD and DF. According to some earthquake relief researches, the injury amount would increase rapidly during T1 period which generally last from the 1st day to 3rd or 7th day after disaster outburst. Then, with the end of golden survivor searching time, the injury amount would increase slightly. So in the expression, we use the actual number of day when DTi<7 and value DTi with 7 when DTi>7.

(2) CIC=f''(DD, DF)

This sub-expression expresses the relationship of CIC and DD, DF. CIC indicate the composition of critical injury, severe injury and walking wounded. The classification of injury is according to the Abbreviated Injury Scale (AIS) which is commonly used in emergency triage. When the DD and DF are higher, the composition of critical injury and severe injury would be higher, vice versa.

(3) CIT=f'''(DTy, DD, DF)

This sub-expression expresses the relationship between CIT and DTy, DD, DF. What injury type would occur in the disaster is determined by the DP while the composition of different injury types are determined by DD and DF.

Level 2-- Country Level Scenario Model for Medical Service Needs Prediction

According to existing researches, with the expansion of time, the amount of injuries caused by the disaster always increasing steadily,, while patients due to the poor coverage of health service, poor sanitary condition, poor immunization and other local health problems gradually increase rapidly that occur in the disaster-stricken population. (Leaning and Guha-Sapir, 2013) This condition could be described in two aspects. One is the new occurrence of patients and diseases, the other is the changes of injury amount and composition of injury condition.

If the local health condition, health coverage and infectious disease control are in good condition, the medical

treatments could decrease the amount of injuries especially the critical or severe injuries. Also, children, maternal women and elderly people with chronic diseases would be taken good care, preventable infectious diseases would under strict control and the health of the disaster-stricken population would be controllable. If the situation is less optimistic or still go towards a bad way, the severe injuries could turn to critical injuries and the critical injuries could lost their life due to the lack of timely medical treatments. The local people especially children, women and the elders could suffer huge humanitarian crisis while infectious diseases could become pandemic.

So we established a country level medical service needs after disaster based on over 1,000 health related indexes monitored by WHO in 194 countries. These indexes are monitored constantly to see if the country could reach the Sustainable Development Goals (SDG) in 2030. We selected 6 types of these indexes to reflect the influence to the medical service needs after disaster.

The outcome indexes of this model are mainly two types. One type reflect the treatment of injuries, such as Injury Amount Adjust(IA-A) and Composition of Injury Condition Adjust(CIC-A). The other type reflect the disease treatment or control condition in period T2, such as Patient Amount (PA)、Disease Composition (DC) and Infectious Disease Epidemic (IDE). When we want use the first type of outcome index, we should use them multiply by the outcome indexes of the level-1 model. Thus, we could get the final injury amount and likely composition of injury condition in period T2.

The income indexes of this model contain two aspects with 6 types of indexes. One aspect of the indexes reflect the resistant capability of the local health service system when facing disaster struck. If these indexes are high, injuries especially severe and critical injuries would be treated quickly and the health service system would soon recover to the normal order. The other aspect of indexes reflects the fragility of the local population health condition. If these indexes are high, new patients and new types of disease would increase rapidly even new infectious disease pandemic would occur. Injuries condition suffered by the disaster would be getting worse due to poor basic health condition. So we call the first aspect of indexes positive indexes which could release the health damage caused by disaster and we mark these indexes with a "+". We mark the second aspect of indexes with a "-" because they have negative effects on disaster medical relief and would worsen the health damage caused by disaster.

The first aspect of indexes include 3 types of indexes which are Health Coverage (HC), Professional Service for Special Population (PSSP) and Infectious Disease Control (IDC). The second aspect of indexes include 3 types of indexes which are General Health (GH), Special Population Health (SPH) and Infectious Disease Composition (IDC).

The abridged general view of the model is shown in Figure3.

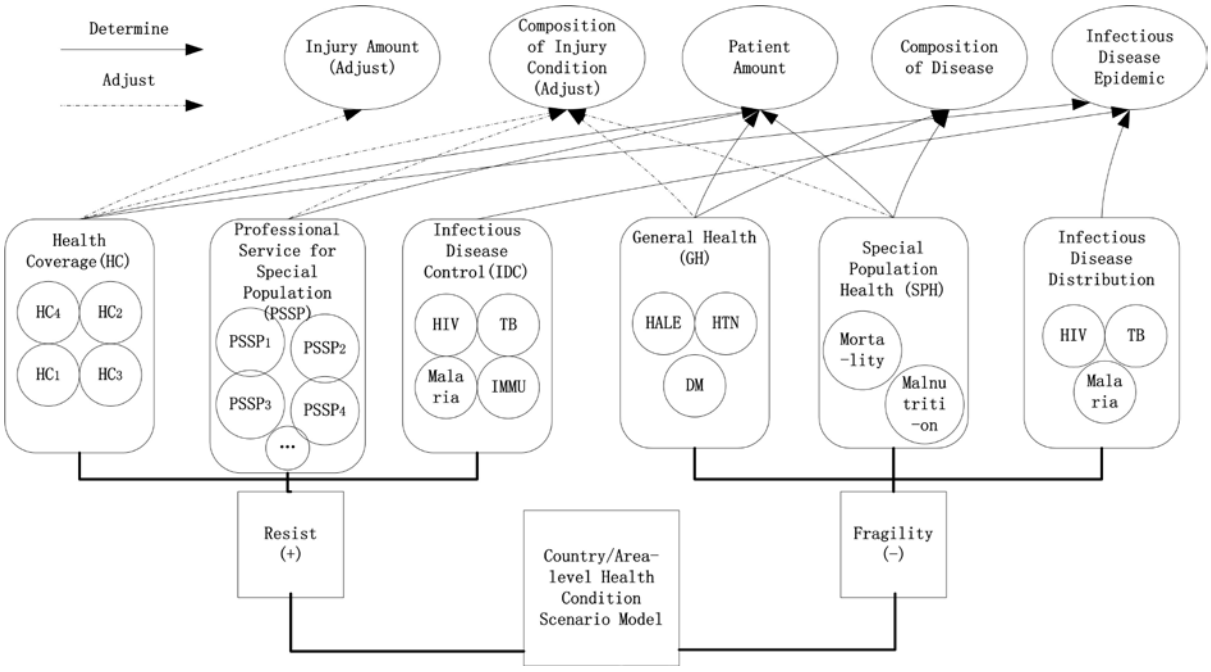

Figure 3. Abridged general view of the country health level model

The mathematical expression of the conceptual model is as follow.

{IA-A, CIC-A, PA, CD, IDE}-g{HC, PSSP, IDC, GH, SPH, IDD}

This mathematical expression could decomposed into 5 sub-expressions.

(1) IA-A= -g'(HC, PSSP)；(2) CIC-A=-g"(HC, PSSP)+g"(GH)

-g' and -g" indicates negative correlation. When HC, PSSP is high which means local health service is good or above the global average level, IN-A and RIC-A is low which means the amount of injury and the ratio of critical or severe injuries decreases. g" indicates positive correlation. When GH is high, RIC-A is high which means the ratio of critical or severe injuries increases.

(3) PA=P*[g'"(GH)-g'"(HC)]+SP*[g'"(SPH)-g'"(SPS)]; (4) DD=-g""(HC, PSSP)+g""(GH, SPH)

P stands for the total population affected by the disaster. SP stands for the special population affected by the disaster including children, women and the elderly. g'" and g"" indicates positive correlation while -g'" and -g"" indicates negative correlation. So these two expressions means the higher value the GH and SPH is, the larger amount of patients and patients with severe diseases would occur. Vice versa.

(5) IDE=-g""'(IDC, HC)+g""'(IDD)

This expression means if the IDC and HC are acceptable in the local area, the possibility of IDE is low. If the area's infectious disease condition is poor which means one or more infectious disease is out breaking, the possibility of new infectious disease pandemic is high. Meanwhile, the members of international medical relief team should take measures in advance such as injecting vaccine or taking precaution measures to prevent infection.

The 6 types of indexes included 20 specific indexes. Table 1 shows the data type presentation, indicators, whether could be graded (e.g. the index of "Basic Hospital Access" could be divided into 4 levels, <10, 10-19, 20-30, >30), global average level and the effectiveness of these indexes.

Table 1. General view of the 20 specific indexes of the country-level model

Factor	Name	abbreviation	Index	Data Type Presentation	Indicator	Whether Graded	Grade No.	Globle Average	Effectiveness
Resist (+)	Health Coverage	HC1	Basic Hospital Access	Ratio	Hospital beds (per 10 000 population)	Yes	4		The higher percentage or ratio could help the country or area to reduce the injury number, release severe wounded and reduce patient number after disaster
		HC2	Health-worker Density	Ratio	Density of physicians (per 1 000 population)	Yes	6		
		HC3	Access to Essential Medicines	Statistic	Median availability of selected generic medicines (%)	No		Public: 37.7/46	
		HC4	Compliance with the International Health Regulations	Percent	International Health Regulations (IHR) core capacity index	Yes	4		
		Other	Mobilization of resources; Sanitation and hygiene	Percent	General government expenditure on health as a percentage of total government expenditure; Population using at least basic sanitation services(%)	Yes	7;4		
	Proffessional Service to Special Population	PSSP1	Family planning	Percent	Married or in-union women of reproductive age who have their need for family planning satisfied with modern methods	No		76	The higher percentage could help reduce child or women injury, release severe child wounded and reduce child or women patient number;
		PSSP2	Antenatal delivery and care	Percent	Antenatal care coverage - at least four visits (%)	Yes	4		
		PSSP3	Health-seeking behavior for child illness	Percent	Children with suspected pneumonia taken to an appropriate health provider (%)	Yes	5		
	Infectious Disease Control	HIV	HIV Therapy	Percent	Estimated antiretroviral therapy coverage among people living with HIV (%)	Yes	5		The higher percentage indicates the country or area could prevent new infectious disease outbreaking at a higher level after disaster.
		TB	Tuberculosis Therapy	Percent	Tuberculosis treatment coverage for all forms of tuberculosis	Yes	4		
		IMMU	Immunization Coverage	Percent	Diphtheria tetanus toxoid and pertussis (DTP3) immunization coverage among 1-year-olds(%)	Yes	4		
fragility(-)	General Health Condition	HALE	Health Adjusted Life Expectancy	Age	life expectancy weighted oradjusted for the level of health-related quality of life	No		59	Lower age and higher percentage indicate poorer health condition which would aggravate the severity of injury and patients as well as the number of patients
		HTN	Prevalence of raised blood pressure	Percent	Percent of defined population with raised blood pressure (SBP≥140 OR DBP≥90)	Yes	5		
		DM	Prevalence of raised blood glucose	Percent	Prevalence of raised fasting blood glucose	Yes	5		
	Special Population Health	Motality	Maternal mortality; Under-five mortality	Ratio	Maternal mortality ratio (by 100,000 live birth); Probability of dying by 5 per 1000 live birth.	Yes	6	216; 40.8	Higher ratio or percentage indicate poorer health condition among children and women which would aggravate the severity of injury and increase special patients.
		Malnutrition	stunting among children under 5 years of age	Percent	Prevalence of stunting among children under 5 years of age	No		22.9	
	Infectious Disease Distribution	HIV	HIV/AIDS	Number	Number of people (all ages) living with HIV Estimates	No		190,155	Higher number indicate higher probability of occuring new infectious disease patients after the disaster
		TB	Tuberculosis	Number	Number of new Tuberculosis cases (per 100 000 population)	No		142	
		Malaria	Malaria	Number	Number of new malaria cases (per 1000 population at risk)	No		94	

We use spider diagram to schematize the country level scenario model. The six directions represent six types of indexes. The left part of the spider diagram indicates positive indexes that present the local resistant capability. The right part of the diagram indicates negative indexes that present the local population's health fragility. Every point on the coordinate presents a value. The middle area of the coordinate indicates the global average level. The further to the center, the higher value it presented. If we connect every point on the each different coordinate, a image would be formed to indicate the combined effectiveness to the medical service needs. If the image's left proportion is larger than the right, the local resistant capability prevails and that would decrease the medical service needs. If the image's right proportion is larger, it is more likely that local people would fall ill or get hurt. If the image's right proportion is larger than the global average level image, international actions are necessary. (Figure 4)

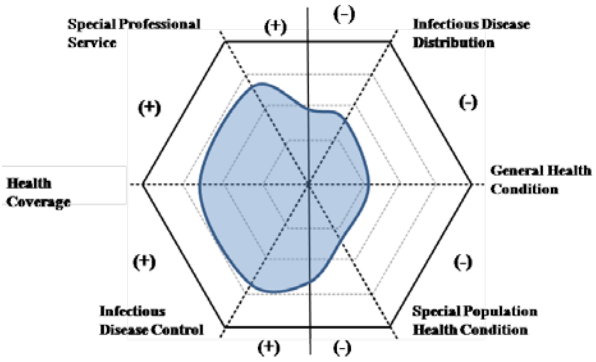

Figure 4-1. Positive Country Level Spider Diagram

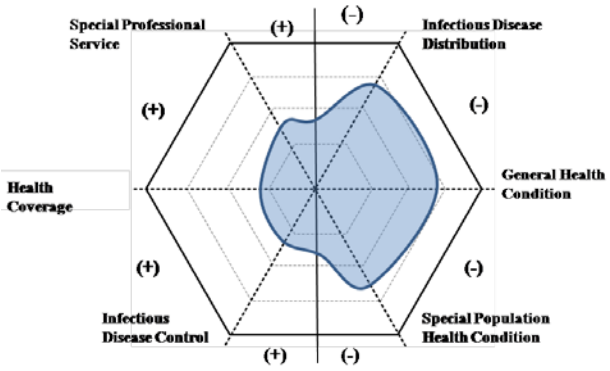

Figure 4-2. Negative Country Level Spider Diagram

RESULT AND DISSCUSSION

Use the double level scenario to analyze the international medical service needs in Yemen and Syrian Arab Republic, both of which out broke armed conflicts.

As shown in table 1, the input indexes' value of the two countries are similar. Both conflicts come of "Arab Spring" which started from 2011. Both conflicts affected the whole country. Both countries have similar location and population. So the outcomes of the 1st level model are similar. As far as this result is considered, which most international medical relief team has done at first, a similar medical strategic readiness plan should be made.

Table 2. Input Indexes of Disaster Level Scenario Model in Yemen and Syria Arab Republic

Nation	Population	Conflict Source	Start Time	Hit Area	Degree of the Conflict
Yemen	25,235,000	Arab Spring	2011	Whole country	Severe
Syria	22,712,000	Arab Spring	2011	Whole country	Severe

We established the second level scenario model for Yemen and Syrian Arab Republic. The value of the input indexes are shown in table 3. We could see from the table, the health condition and health coverage of the two countries are different. From a rough comparison, health related situation in Syrian Arab Republic is better than Yemen.

Table 3. Input Indexes of Country Level Scenario Model in Yemen and Syria Arab Republic

Factor	Name	abbreviat-ion	Index	Yemen	Syrian Arab Republic	Globle Average
Resist (+)	Health Coverage	HC1	Basic Hospital Access	7 grade:1	15 grade:2	grade:2
		HC2	Health-worker Density	0.311 grade:1	1.546 grade:3	grade:3
		HC4	Compliance with the International Health Regulations	46 grade:2	63 grade:3	grade:2
		Other	Mobilization of resources; Sanitation and hygiene	3.93/60 grade:1/2	4.8/93 grade:1/4	grade:4/2
	Professional Service to Special Population	PSSP1	Family planning	69.6	87.5	76
		PSSP2	Antenatal delivery and care	49.1 grade:2	91.1 grade:4	grade:2
		PSSP3	Health-seeking behavior for child illness	34 grade:2	76.8 grade:4	grade:3
	Infectious Disease Control	HIV	HIV Therapy	No data	18 grade:1	grade:3
		TB	Tuberculosis Therapy	59 grade:2	80 grade:3	grade:2
		IMMU	Immunization Coverage	DTP3:84 grade:3	DTP3:70 grade:2	grade:2
	General Health Condition	HALE	Health Adjusted Life Expectancy	54	63	59
		HTN	Prevalence of raised blood pressure	30.7 grade:4	24.5 grade:2	grade:3
		DM	Prevalence of raised blood glucose	11.3 grade:4	14.6 grade:5	grade:3
Fragility (-)	Special Population Health	Motality	Maternal mortality; Under-five mortality	385;47	68;17.4	216; 40.8
	Infectious Disease Distribution	HIV	HIV/AIDS	No data	9,900	190,155
		TB	Tuberculosis	48	21	142
		Malaria	Malaria	22.2	0	94

Data source: WHO's The Global Health Observatory theme pages. (http://www.who.int/gho/en/)

Schematizing the model inputs with spider graphic, we could see the difference between the two countries from Figure 5. In figure 5-1, the area which indicates health coverage is smaller than global average level and while the area indicates population health condition is larger. This indicates the same degree armed conflict could cause lager health damage as well as a higher possibility of humanitarian crisis to the people in Yemen. Lower health coverage also indicate a possibility of pandemic infectious disease that are transmitted through water or air. Comparing figure 5-1 and 5-2, the value of IDC in Syria is lower than in Yemen, especially the vaccination level. This indicate it is more likely that a infectious disease which has immunoprophylaxis method would pandemic in Syria. But the IDC capability index implies that the epidemic situation in Syria would be better in Yemen. When we multiple the level-2 model outcome with level-1 model, the medical service needs prediction are mainly the outcome of level-2 model which indicate that we should make a more urgent and plentiful international medical relief readiness plan and mobilize more sufficient international medical resource support for Yemen than Syria.

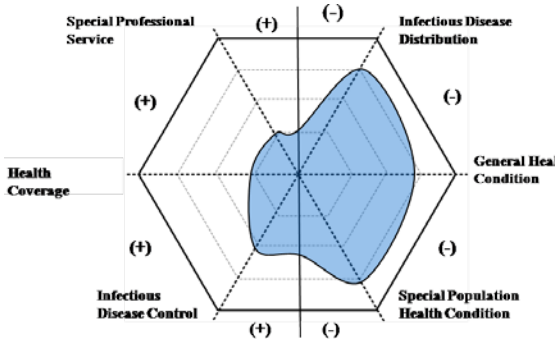

Figure 5-1. Country Level Spider Diagram of Yemen

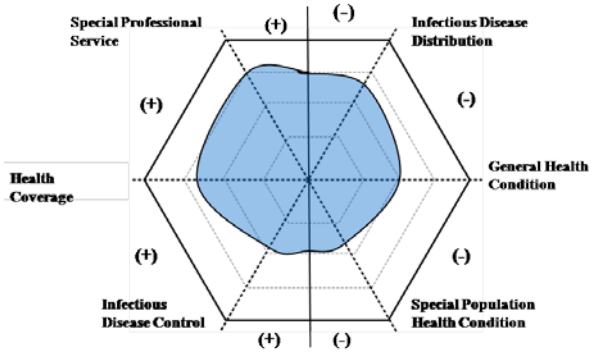

Figure 5-2. Country Level Spider Diagram of Syria

From the WHO reports, the two countries had different medical needs. According to reports, the number of people in need of humanitarian assistance is 20.7 million in Yemen while the number in Syria is 13.1 million. The number of people in acute need of humanitarian assistance is 9.8 million in Yemen while the number in Syria is 5.6 million. In Yemen, 1.8 million children acutely malnourished. In Syria, the situation is better, 19,000 children acutely malnourished. Cholera out broke in Yemen and the cumulative total from 27 April 2017 to 14 Jan 2018 is 1,035,676 suspected cholera cases and 2,244 associated deaths. Polio out broke in Syria and the total number of cVDPV2 cases from Jan 2017 to Jan 2018 is 78.

From these facts, it can be concluded that the medical service needs in Yemen are more urgent and complex than in Syria. More international actions are needed in Yemen. From the WHO's new response plan for these two countries, we could see that the main points in Yemen's plan are more emergent medical resources delivery and life-saving medical services supports and trainings. Syria's plan focuses mainly on helping the local health service system to recover and supporting polio vaccination.

The outcomes and indications of the double-level scenario model fit this reality.

If only the disaster-level model is considered, international medical relief team tends to make similar readiness plan for Yemen and Syria. When the country-level model were also considered, it becomes clear to see the difference of medical service needs and different readiness plan suggestions gradually form.

CONCLUSION AND NEXT RESEARCH PLAN

When predicting the medical needs in international disaster relief actions, research should pay equal attention to the disaster scenario and the local medical and health scenario. In order to establish a more fit-to-reality medical readiness plan could be made. This research aims to establish a double scenario model for medical service need prediction. This research established the frame of the model (as shown in Figure 6) and two conceptual expressions of the model.

The model can be consummate by some improvement, such as: relationship between the inputs and outcomes should be more clear and calculable. Each index might have different weight in the model and the weight might change with time. The sensitivity analysis of the model is also needed. More case studies are needed to check the effectiveness of the model as well. Further research plans are making and more research measures are taking.

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