Physician Manpower Mobilization After a Major Disaster in Taiwan

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Objectives. In the initial hours following a major disaster, emergency departments must cope with mass casualties. The efficiency of physician manpower mobilization affects the supply of medical care. The purpose of this study was to analyze the pattern of manpower mobilization and to assess the capacity of medical care at EDs in the field to improve the efficiency of the medical response after a disaster.

Methods. In this study, we assessed physician manpower following the Chi-Chi earthquake in Taiwan on 21 September 1999. Data on the number of patients were collected from hospitals in three major disaster sites. The hospital treatment capacity was analyzed by de Boer's rule and the American College of Emergency Physicians (ACEP) physician treatment capacity rule.

Results. The average rate of physician mobilization was 12% per-hour in the initial 2 hours, while the rate from the 2nd to 6th hour was 6% per-hour. The capacities of hospitals with the most mass casualties varied considerably. The hospitals with the most mass casualties lacked sufficient physician manpower in the initial post-quake hours.

Conclusions. The requirement and utilization of physician manpower in the crucial period after a large scale disaster remains a great challenge for the medical disaster response system. In designing disaster response protocols, physician manpower should be expanded to include non-hospital physicians in the initial hours after major disasters. **(Mid Taiwan J Med 2004;9:19-26)**

Key words

disaster, emergency department, hospital capacity, physician manpower, earthquake

INTRODUCTION

Central Taiwan suffered a major earthquake in the early morning of 21 September 1999. The fault line traverses three main areas of central Taiwan. More than 2,000 people died and 8,000 people sustained injuries in these three affected areas. Hospitals located nearer the fault received mass casualties after the quake. Most of the victims arrived at an ED in the initial hours [1]. Many patients arrived at an ED by any available mode of transport soon after the quake. This pattern of patient influx was seen again at EDs in New York City following the terrorist attacks on the World Trade Center (WTC) on 11 September 2001. The influx of victims to the four hospitals closest to the fault peaked between 2 and 3 hours after the quake, and approximately 50% of patients received care within 7 hours. Additionally, only one-fourth (26%) of the total number of patients arrived at the hospitals in an emergency medical vehicle [2]. Owing to the large number of patients and time constraint, patients were rushed to the ED rather than treated at the site.

Pretto et al demonstrated that there were many victims whose deaths might have been prevented if they had received medical attention in the first six hours after the tremor [3,4]. About 25% to 50% of the patients could have been saved if emergency care had been rendered at once [5]. Therefore, it is imperative for a medical response system to be maximally efficient so that medical

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care can be administered as soon as possible after a disaster to reduce mortality and morbidity rates. Patient mortality has been related to the number of physicians, which is one of only a few controllable factors following a major disaster [6]. Although multiple factors affect the treatment capacity of a hospital, physician manpower (PM) is still the key factor in any emergency medical disaster response. Exactly how many physicians are required to manage mass casualties has not been clearly established and there are currently few available data on the subject [7].

In order to improve medical care efficiency, it is necessary to evaluate ways to increase the effectiveness of mobilization of a large number of physicians from all available sources and to upgrade the disaster medical assistance response. It is dangerous to depend on outside medical assistance, because it usually arrives too late for immediate care in the initial hours because of to limited mobilization and communication. Initial emergency medical needs are therefore best met by local providers [8]. PM represented the treatment capacity of a hospital. The purpose of this study was to evaluate the pattern of manpower mobilization and to assess the capacity of medical care at EDs in the field in order to improve the efficiency of medical response in the initial hours after a disaster.

MATERIALS AND METHODS

The hospital data on the number of patients and mortality rates of quake victims at EDs in three main disaster sites through which the fault line passed (sites A, B and C) were collected in person or by mail. The physician manpower at EDs at the second and the sixth hour after the quake was determined by checking staff records at EDs, and by interviewing chiefs-of-staff at EDs in person or by telephone. The medical resources data in the three sites, such as the number and level of hospitals in 1999, were collected from the Taiwan Medical Association (TMA).

Hospital treatment capacity (HTC) is defined as the number of victims who could be treated per hour in the hospitals, according to de Boer's rule, and is generally estimated to be 3% of the total number of beds [7]. In the current study, the HTC in the 12 hospitals with the largest mass casualties in the field in the initial 6 hours was calculated according to de Boer's rule using the following formula:

$HTC_{0\text{-}6} = 3\% \times$ No. of hospital beds $\times$ 6 (h)

The American College of Emergency Physicians (ACEP) recommends that physicians' services be provided at a rate of approximately 2.75 patients per hour [9]. According to ACEP's physician treatment capacity rule, we expected that PM would increase in a linear manner over these two time periods (hours 0-2 and hours 2-6; hour 0 was the time of the quake). Total physician manpower was defined as the number of physicians at one hospital. PM_0 was defined as the number of on-duty physicians at the ED before the quake. PM_1 was defined as the number of physicians at the ED in the first hour post-quake; PM_2 was the number of physicians at the ED in the second hour, and so on. The physician mobilization increasing rate (PMIR) in the first two hours ($PMIR_{0\text{-}2}$) was defined as the manpower increasing rate per hour at the ED in the first two hours. The PMIR from the 2nd to 6th h ($PMIR_{2\text{-}6}$) was defined as the physician manpower increasing rate per hour at the ED from the 2nd to 6th hours. Therefore, PM during these two time periods, the first two hours and the 2nd to 6th hours after the quake, was:

$PM_1 = PM_0 + TPM \times PMIR_{0\text{-}2}$

$PM_2 = PM_1 + TPM \times PMIR_{0\text{-}2}$

$PMIR_{0\text{-}2} = (PM_2 - PM_0)/2$ h

$PM_3 = PM_2 + TPM \times PMIR_{2\text{-}6}$

$PM_4 = PM_3 + TPM \times PMIR_{2\text{-}6}$

$PMIR_{2\text{-}6} = (PM_6 - PM_2)/4$ h

The HTC in the 12 hospitals with the largest mass casualties in the field in the initial 6 hours was calculated according to ACEP's rule by the following formula:

$HTC_{0\text{-}6} = \sum_{n=0}^{6} 2.75 \times PM_n$

(PMn: physician manpower per hour post quake)

The difference between PM and PMIR in the two periods, as well as HTC by Boer's and ACEP's rule was analyzed by paired *t* test. A *p*

Table 1. The basic data of medical resources in central Taiwan in 1999

Field data	Site A	Site B	Site C
Number of injured	1112	2421	3606
Number of killed	113	1135	857
Physicians/Km^2	13.21	0.65	0.10
Total no. of physicians	2140	1350	470
Worked in hospitals (%)	1384 (64.7)	644 (47.7)	207 (44.0)
Non-hospital physicians (%)	756 (35.3)	706 (52.3)	263 (56.0)
No. of EMTs	172	227	148

EMT = emergency medical technician.

Table 2. The EDs with most mass casualties (top 12) in three sites after earthquake in Taiwan in 1999

Hospital no.	Location (Site)	No. of beds	No. of physicians	No. of patients	No. of deaths at ED
1	C	236	39	754	58
2	C	144	25	541	58
3	C	158	17	512	22
4	B	40	15	450	40
5	B	464	87	445	47
6	B	64	13	440	80
7	A	1290	406	375	22
8	A	458	83	337	22
9	A	482	78	327	58
10	C	285	50	231	34
11	C	167	14	212	16
12	C	132	13	190	16
Total		3920	840	4814	473

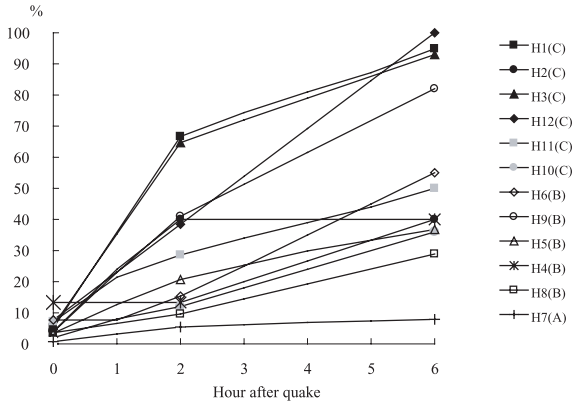

Figure. The physician mobilization rate at hospitals with the most mass casualties (top 12) at three sites in Taiwan following the 21 September 1999 earthquake. Abbreviations are used for all hospital names and sites A, B and C are indicated in parentheses.

value of < 0.05 was considered statistically significant.

RESULTS

Sixty-nine hospitals provided emergency medical services in the three sites in 1999. Among these, data from 50 hospitals were collected (respondent rate = 72%): 16 hospitals in site A, 22 in site B and 12 in site C. Two hospitals that were severely damaged in the quake were excluded because of insufficient quantity and quality of data. The ratios of hospital physicians to non-hospital physicians were 1.9 to 1, 0.9 to 1 and 0.8 to 1 in sites A, B and C, respectively. The numbers of patients and deaths were greater in the counties, but the hospitals' capabilities and resources were less than those of hospitals in the cities (Table 1).

The average number of patients at EDs in the affected areas was 185 ± 176 on 21 September 1999. The basic data for the 12 hospitals with the largest mass casualties are shown in Table 2. Among them, 6 hospitals were located in site C, 5 hospitals in site B and 1 hospital in site A. The average number of quake-related casualties was 401 ± 160 while the

Table 3. The mobilization of physicians before and after the quake at 12 hospitals with the highest mass casualties following the 21 September 1999 earthquake

Hospital no.	TPM	No. of physicians at EDs (%)			PMIR (% / h)	
		Before quake	2nd hour after quake	6th hour after quake	1st-2nd hour	2nd-6th hour
1	39	2 (5)	26 (67)	37 (95)	31	7
2	25	1 (4)	10 (40)	10 (40)	18	0
3	17	1 (6)	11 (65)	16 (94)	29.5	7.3
4	15	2 (13)	2 (13)	6 (40)	0	1
5	87	3 (3)	18 (21)	32 (37)	9	4
6	13	1 (8)	2 (15)	7 (54)	3.5	9.8
7	406	3 (1)	22 (5)	32 (8)	2	0.8
8	83	1 (4)	8 (9)	24 (29)	2.5	5
9	78	1 (4)	32 (41)	64 (82)	18.5	10.3
10	50	1 (2)	6 (12)	18 (36)	5	6
11	14	1 (7)	4 (29)	7 (50)	11	5.3
12	13	1 (8)	5 (38)	13 (100)	15	15.5
Mean ± SD		5 ± 3	29 ± 21	55 ± 30	12 ± 10	6 ± 4
p			0.002		0.061	

TPM = total physician manpower; PMIR = physician mobilization increasing rate.

Table 4. Comparison of the maximum number of patients treated at 12 hospitals in the field by de Boer's rule and ACEP's physician treatment capacity rule in initial six hours after disaster

Hospital no.	No. of patients in initial 6 hours* (A)	HTC by de Boer's rule (B)	(B) – (A)	HTC by ACEP's rule ± (C)	(C) – (A)
1	377	43	–334	475	98
2	272	17	–255	154	–118
3	256	19	–237	209	–47
4	225	5	–220	66	–159
5	223	56	–167	388	165
6	222	8	–214	72	–150
7	188	155	–33	421	233
8	169	55	–114	245	–76
9	164	58	–106	718	554
10	116	34	–82	179	63
11	106	20	–86	91	–15
12	95	16	–79	135	3
Mean ± SD	201 ± 80	41 ±41	–160 ± 91	263 ± 199	28 ± 192
p		< 0.001		0.136	

*It was assumed that 50% of the total number of patients on the first day after the quake arrived in the initial 6 hours. HTC = hospital treatment capacity.

number of quake-related deaths at EDs was 39 ± 21 in these 12 hospitals. The PM before the quake (PM_0) in these 12 hospitals was 5 ± 3% of the total physician manpower. The average physician mobilization rate at EDs was 29 ± 21% in the second hour after the quake which increased to 55 ± 30% in the sixth hour (Figure). The PMIR was 12 ± 10% per hour in the initial 2 hours, while the PMIR from the 2nd to 6th hour was 6 ± 4% per hour (Table 3). The *p* value was 0.061. The average PMIR was 18.3% per hour in the initial 2 hours in site C hospitals and 6.7% in site B hospitals. Table 4 compares the HTC according to de Boer's recommendation and ACEP's rule in the initial 6 hours. The negative values indicate insufficient treatment capacity, and positive values indicate sufficient treatment capacity. According to de Boer's rule, manpower was insufficient in all 12 hospitals ($p < 0.001$), although according to ACEP's rule, only half of

the hospitals lacked sufficient PM ($p = 0.136$).

DISCUSSION

The number of injuries and deaths caused by the Chi-Chi earthquake was greatest in three fields in central Taiwan. In the current study, the number of EMTs was insufficient in the three affected areas in central Taiwan, and this insufficiency limited the pre-hospital medical care, triage, transportation and diversion of patients. In addition, because of the deficiency in the number of ambulances, patients were sent to hospitals by other modes of transport. This meant that EDs in the sites had to cope with mass casualties very early with little or no prior notification, common a situation. It is after a major disaster [10-12]; therefore, it is essential, for medical resources to be made available to patients in the crucial first hours. Many studies have shown that affected areas rely on their own medical resources in the initial hours after a disaster [13-15]. Hence, the speed of physician mobilization is crucial. As our data show, the number of injuries and mortalities was quite high, but the physician density as well as the number and percentage of physicians working at hospitals in suburban (site B) and rural (site C) areas were lower than in urban areas (site A). This suggests that the efficiency of physician manpower mobilization and utilization in these areas was important.

In the hospitals with the most mass casualties (top 12), over 4800 injured (67%) patients were treated and 473 (22%) patients died. However, there were only 840 hospital physicians in the region who were poorly mobilized. The HTC of these 12 hospitals in the first 24 hours was 2800 patients by de Boer's rule. It is very clear that treatment capacity was inadequate. Due to insufficient numbers of physicians, the physician mobilization in the initial hours after the earthquake became a crucial factor that affected the treatment capacity in the fields. The HTC was related to number of hospital beds, but the PTC was related to the number of physicians. If PTC can be improved, it may alleviate the crisis. As our data demonstrate, PMR varied in the site hospitals. The PMIR in the initial 2 hours after the quake was 12 $\pm$ 10%. PMIR in the first two hours was higher than in the following four hours. The PMR of hospitals appeared to be related to the scale of the site damage where the hospitals were located. The efficiency of physician mobilization was better in rural hospitals than in suburban or urban hospitals. Most of the high PMR was due to physicians living at hospital-owned apartments located just behind the hospitals. Hospital managers should be aware of the mobilization rate of their hospital. Mobilization of hospitals' physicians may be limited by many factors [1]. After a major disaster, the communication system or transportation system may be dysfunctional. Physicians' behavior becomes very important in physician mobilization. Physicians must be made aware of the vital importance of responding immediately in the event of a major disaster. They must be instructed to go directly to the hospital after a disaster to increase physician manpower during the initial crisis. Hospitals' disaster training programs and disaster planning should include this issue.

The PM at hospitals in the current study was confirmed to have been insufficient in the initial hours post-quake by de Boer's rule. According to ACEP's PTC rule, PM was sufficient in about 50% of the hospitals and was therefore insufficient in approximately half of the hospitals. In fact, these results were obtained by conservative calculations, because for de Boer's rule, when disasters occur at night, the HTC tends to decrease. Physicians play a vital role following a disaster. However, the efficiency of physician manpower mobilization and utilization of non-hospital physicians in the community has seldom been discussed in detail [16]. The number of physicians working at hospitals at the time of the earthquake was less than that of non-hospital physicians (local practitioners). Therefore, it is essential that local medical disaster planning includes mobilization of non-hospital physicians. The manpower of non-hospital physicians may have been overlooked in disaster planning for a number of reasons: 1) In many previous disasters,

mass casualties occurred on the second day so that the physician mobilization was not so important [17-19]. 2) Manpower after previous disasters has typically been reported as sufficient [2,19]. 3) Victims may have the option of visiting a physician's office or clinic if a disaster occurs during the daytime [20].

The relationship between physicians and number of patients is difficult to judge. Insufficient PM after the quake may have decreased the quantity and quality of emergency resuscitation which may, in turn, have resulted in increased numbers of preventable deaths and injuries. Disaster medicine does not simply involve responding to the acute medical needs of large numbers of injured persons at a disaster site. We need to consider how to coordinate physicians from all sources in the community in preparation for all kinds of future disasters. Emergency physicians, hospital physicians, outside physicians as well as non-hospital physicians need more training so that they can be incorporated into the medical disaster response system. Our data revealed that under normal conditions, there were fewer hospital physicians in two affected counties. At the crucial time, additional physicians may be required to provide essential medical care. Recruitment of non-hospital physicians could resolve the problem of manpower shortage when there is a sudden influx of patients into the ED after a disaster at night or at other special times. If the disaster plan neglects this medical resource, and relies on the EMSS, outside medical assistance and physicians at hospitals, the death rate may be needlessly high in future disasters, particularly in those that occur during the night or on national holidays. Disaster medicine must emphasize teamwork among physicians. For example, in bioterrorism response systems, emergency physicians, outpatient primary care physicians and other practitioners participate in the early recognition and surveillance for bioterrorism [21]. Although there is a need for physicians in the same community to work together in any bioterrorism response, there is an even greater need for close coordination of physicians in the community to respond to future disasters.

Disasters of all kinds may occur at any time or place, so it is vital to improve upon existing disaster protocols. Many factors affect the scale of injuries and mortalities. A vital and controllable factor in treatment and resuscitation is the number of physicians. The key factor affecting the number of physicians in the first few hours is the efficiency of physician mobilization. All physicians should acquire some basic training and knowledge in disaster medicine to prepare for future disasters in order to reduce the number of preventable injuries and deaths. In addition, we suggest that the PM resources should be expanded to include non-hospital physicians in the site, especially in areas with low hospital PM. Emergency physicians have a responsibility to organize all available PM and set up training programs in disaster medicine for non-ED physicians, such as hospital physicians or non-hospital physicians to improve the emergency medical care after a disaster.

REFERENCES

1. Chen WK, Cheng YC, Ng KC, et al. Were there enough physicians in an emergency department in the affected area after a major earthquake? An analysis of the Taiwan Chi-Chi earthquake in 1999. *Ann Emerg Med* 2001;38:556-61.
2. CDC, National Center for Injury Prevention and Control. Rapid assessment of injuries among survivors of the terrorist attack on the World Trade Center --- New York City, September 2001. *MMWR* 2002;51:1-5.
3. Pretto EA, Angus DC, Abrams JI, et al. An analysis of prehospital mortality in an earthquake. Disaster Reanimatology Study Group. *Prehospital Disaster Med* 1994;9:107-17.
4. Pretto EA, Ricci E, Klain M et al. Disaster reaminatology potentials: a structured interview study in Armenia. III. Results, conclusions and recommendations. *Prehospital Disaster Med* 1992; 7:327-37.
5. Safar P. Resuscitation potentials in mass disasters. *Prehospital Disaster Med* 1986;2:34-47.
6. Liang NJ, Shih YT, Shih FY, et al. Disaster epidemiology and medical response in the Chi-Chi earthquake in Taiwan. *Ann Emerg Med* 2001;38:549-55.

7. de Boer J, Brismar B, Eldar R, et al. The medical severity index of disasters. *J Emerg Med* 1989;7:269-73.
8. Noji EK. Evaluation of the efficacy of disaster response: research at the John Hopkins University. *UNDRO News* 1987:11-3.
9. Graff LG, Wolf S, Dinwoodie R, et al. Emergency physician workload: a time study. *Ann Emerg Med* 1993;22:1156-63.
10. Jacobson S. Recollections of September 11. Society for Academic Emergency Medicine Web site. Available at: http://www.saem.org/newsltr/2001/novdec/septembe.pdf. Accessed July 12, 2002.
11. Jagim M.ENA president visits hospitals affected by September 11 attacks. Emergency Nurses Association Web site. Available at: http://www.ena.org/publications/connection/ena-president.asp. Accessed July 12, 2002.
12. Quarantelli EL. Delivery of emergency medical services in disasters: assumptions and realities. New York: Irvington, 1985.
13. Baba S, Taniguchi H, Nambu S, et al. The Great Hanshin earthquake. *Lancet* 1996;347:307-9.
14. Tanaka-H, Iwai-A, Kuwagata Y, et al. Overview of evacuation and transport of patients following the 1995 Hanshin-Awaji earthquake. *J Emerg Med* 1998;16:439-44.
15. Kuwagata Y, Oda J, Tanaka H, et al. Analysis of 2,702 traumatized patients in the 1995 Hanshin-Awaji earthquake. *J Trauma* 1997;43:427-32.
16. Witt JL. National disaster plans crucial; local practitioner readiness essential! *Acad Emerg Med* 1995;17:1021-2.
17. Thiel CC, Schneider JE, Hiatt D, et al. 911 EMS process in the Loma Prieta earthquake. *Prehospital Disaster Med* 1992;7:348-58.
18. Noji EK, Kelen GD, Armenian HK, et al. The 1988 earthquake in Soviet Armenia: a case study. *Ann Emerg Med* 1990;19:891-7.
19. Pointer JE, Michaelis J, Saunders C, et al. The 1989 Loma Prieta earthquake: impact on hospital patient care. *Ann Emerg Med* 1992;21:1228-33.
20. Durkin ME. Injuries and emergency medical response in the Loma Prieta Earthquake. Bulletin of the Seismological Society of America. 1991:2121.
21. Gerberding JL, Hughes JM, Koplan JP. Bioterrorism preparedness and response: clinicians and public health agencies as essential partners. *JAMA* 2002; 287:898-900.

台灣地區發生大災難後醫師人力的動員

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目的 發生大災難後，災區急診在前幾小時面臨大量傷患的湧入。醫師人力動員的效率影響提供醫療照護的多寡。本研究的目的在分析醫師動員的型態，以及災區醫院提供醫療照護的能量，作爲提昇災難發後初期的應變效率。

方法 本研究收集1999年9月21日，集集地震三個主要災區醫院的病人數，以及醫師人力的動員情形，醫院處置能量是以De Boer's 計算，醫師處置能量則以美國急診醫學會的算法來進行分析及比較。

結果 分析處理病患數最多的前12家醫院醫師的動員率，在前2小時是每小時12%，而在第2及第6小時時降至每小時6%，在這樣的動員情形下，每一家醫院所能照護的能力差異很大，大部份的醫院初期的醫師人力仍是不足。

結論 大災難發生後的最危急時期，人力的需求以及利用，仍是醫療應變系統最主要的挑戰。醫院在規劃災難應變計劃時，醫師人力必須考慮非醫院醫師的支援。（中台灣醫誌 **2004;9:19-26**）

關鍵詞

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