Designation of a New Training Model of a Local Disaster Medical System with Tabletop Exercises

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Background: A new model of a local disaster medical system (LDMS) was proposed through the consensus method of expert panel meetings for county governments in Taiwan. This LDMS model adopts a local emergency medical response system (EMRS) for dealing with daily accidents as a basic structure by expanding its roles and functions. The objective of this study was to determine the feasibility of the new LDMS model by evaluating its initial phase response to simulated disasters using tabletop exercises.

Methods: Two tabletop exercises were held after the responders of the LDMS were trained according to the new model. Forty and 42 participants respectively joined the 2 tabletop exercises, which simulated an earthquake causing 400 casualties in 6 different locations in order to apply the new LDMS model. The outcome measurements of the tabletop exercises were the mean accuracy rate of victim triage and disposition, and medical interventions.

Results: About 92% of victims were correctly triaged, and 88% had a correct disposition. Moreover, around 86% of all victims received adequate medical interventions. All victims were dispatched to appropriate facilities or treatment areas within 45 min.

Conclusion: The new EMRS-oriented model of this LDMS can respond quickly, efficiently, and adequately to the initial phase of a disaster during tabletop exercises. Further clinical investigations are required to prove the efficacy of the new LDMS model in real disasters or in full-scale drills.

(Chang Gung Med J 2003;26:879-88)

Key words: **emergency medical services, mass casualty incident, disasters, disaster planning.**

Taiwan is prone to both natural and man-made disasters with a board spectrum of magnitudes. Geographically, the island is located in the West Pacific, where typhoons, floods, landslides, and earthquakes are a constant threat. Casualties associated with recent disasters have increased significantly owing to population growth, inappropriate urbanization, and poor management of slope-land. Over the past 10 years, 2,936 fatalities have occurred and 12,708 victims have been injured in Taiwan during disasters.[1] Recently, the most devastating catastrophe was the Chi-Chi earthquake on 21 September 1999, which shook central Taiwan with a magnitude of 7.3 on the open-ended Richter scale. This earth-

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Received: Dec. 18, 2002; Accepted: Jul. 11, 2003
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quake killed 2,347 people, injured another 1,130 victims, and damaged an estimated 107,002 buildings.[2] Recently, determining how to establish an effective disaster medical system has become an issue of great public concern in Taiwan.

Taiwan passed a disaster prevention and relief law in 2000. This law designates county governments as the primary agencies for establishing a structure for the systematic, coordinated, and effective response to major disasters and emergencies within their jurisdictions. Moreover, the law defines the role of the central government as the maker of fundamental policies, and organizer of inter-agency and inter-county governmental resources to assist the affected counties. The framework and functions of disaster medical systems are well documented in the medical literature.[3,4] However, significant diversity exists in local medical disaster planning and systems among most countries. Obviously, these differences may be due to the different infrastructure in various communities. Most county governments in Taiwan have not set up their local disaster medical system (LDMS). The key problem has been the lack of a template for designing systems.

A disaster response development project funded by the government was conducted in 2001 to devise a new domestic LDMS model for county governments in Taiwan. The project determined the basic structure, policies, operating concepts, and response actions of the system, as well as the roles and responsibilities of local agencies and outside resources. A new model of an LDMS was proposed through the consensus method of expert panel meetings. The setting of this development project was Taoyuan County, northwestern Taiwan which has a population of 1.7 million and an area of about 1220 km^2. In addition, the project researchers were comprised of 21 individuals invited to participate in the expert panel, including scholars and key representatives from all emergency response agencies in Taoyuan County. This study was the testing phase of the project. The aim was to determine the feasibility of the new model of the LDMS by evaluating its initial phase response to simulated disasters during tabletop exercises.

New model of LDMS

The details of the new LDMS model are not covered in this article, but only the principal parts of the system design, the idea of its origin, and the initial phase response plan are briefly described here.

Common management philosophies of disaster systems assume that a large number of casualties and heavy damage to the basic infrastructure will overwhelm the capabilities of local governments and highlight that outside resources or special response agencies must be introduced on short notice in order to initiate an effective response.[4] Some European models of disaster preparedness are analogous to the concept of civil defense in general. The army provides a command system, field victim medical care, logistics, communications, and patient transportation, whereas the civilian health and medical system has the responsibility only for definite medical care.[5] We assumes that the disaster medical response depends solely on outside resources or that extraordinary response structures are unreliable. Therefore, a consensus by the expert panel concerning the basic structure of the LDMS adopted the principle of "local agencies as the key resources" by expanding the roles and functions of local "daily" emergency medical response system (EMRS).[6] The proposed model is quite similar to the disaster model used by local governments in the US which stress that the backbone of successful disaster response lies with local jurisdictions.[7]

The EMRS of most counties in Taiwan have 2 major components, the emergency medical service system (EMS) providing pre-hospital medical care and the hospital emergency medical care system which includes all trauma services and emergency departments of general hospitals in the county. The EMS is run by the county fire department, and firefighters have received basic or intermediate emergency medical technician (EMT) medical training in order to fulfill this mission. Today, on average, about 56% of firefighters have received 264 hours of EMT level II training and can provide basic life support medical care, not including airway intubation or medication.[8] A recent change is that now an EMT is allowed to perform automatic external defibrillation in Taiwan. The local EMRS deals with daily accidents and medical emergencies and is coordinated by the Bureau of Health of county governments. Radio communication by the EMRS is controlled by the central dispatch center of the fire department. Mass-casualty incident (MCI) exercises are held annually for the EMRS. Notably, integration of the local disaster medical assistant team (DMAT) with the EMRS is the final accomplishment for establishing an LDMS. In cooperation with other medical response agencies, local DMAT and EMRS are assigned as the major operational arms of the system. Once a local DMAT is activated, team members can be deployed as an entire team or divided into small medical operation units (MOUs) containing a minimum of 5 team members. The emergency operations center (EOC) of the local DMAT is established at the training base hospital for information gathering, tactical planning and command, liaison, and dispatching the MOUs and medical supplies.

Top principal policies of an LDMS are to maintain a well-organized initial emergency response to disasters. This well-organized response is based on adequate scene evaluation, victim triage, an effective command system, and viable communications. The system is designed to function in a self-sustained manner for the first 12 hours. Responses of an LDMS ensure the provision of emergency life-saving interventions or initial stabilization to the upper limits of its management capacity. Outside resources are then introduced as appropriate and preparations are made to evacuate patients to non-affected areas.

METHODS

The disaster response development project proceeded through planning, training, and testing phases. The planning phase was aimed at deriving the basic structure, operational concepts, and response plan of the LDMS through the consensus method of expert panel meetings. During the training phase, 3 training courses were held to introduce the new model to members of the local DMAT. Two further disaster medical response training courses then ensured that the new system and its response plan were understood by other disaster medical responders in Taoyuan County. A tabletop exercise was scheduled for the final session of both training courses. For the testing phase, these 2 tabletop exercises, involving respectively 40 and 42 previously trained medical personnel, were taken as convenience samples to determine the feasibility of the new model of LDMS. Then the test model was modified into a working model after the final revision meetings that followed the tabletop exercises. The scope of this study focuses on the testing phase of the project.

Tabletop exercise

The tabletop exercise can be referred to as a tactical exercise without victims simulated by actors. In fact not just 1 table was used, but rather several tables and the floor of a large hall were required. The exercise was designed to test a scenario in which an earthquake measuring 6.5 on the Richter scale strikes the county and causes 6 major incidents at different locations. The exercise represented a total of 400 victims using numbered paper cards marked with individual identities and injuries which placed them in 1 of the triage categories. The disaster triage method, employed in the tabletop exercises, differs from MCI triage in philosophy. MCI triage is commonly used by pre-hospital providers, and emphasis is placed on physiological parameters to sort the sickest victims. The focus of the disaster triage method shifts to resource management considerations and distribution of patients for definite medical care.[9] It follows the principle of providing "the greatest good for the greatest number". This is approached initially by identification of injured victims at the extremes of injury, placing those classified as hopeless or non-salvageable victims in category IV. On the contrary, victims with salvageable, life-threatening conditions are triaged as category I. Victims without life-threatening conditions but who require hospitalization are triaged as category II, while those not requiring hospitalization are triaged as category III. The triage category of each card victim was predetermined. The proportions of the card victims among the 4 predetermined triage categories were 16% (65/400) as category I, 24% (94/400), 50% (201/400), and 10% (40/400) as categories II, III, and IV, respectively, for each tabletop exercise.

Participants were asked to apply the new LDMS model, and they wrote the management for each card victim they encountered at the simulated incident sites or treatment areas, including the victim triage category, required medical interventions, dispositions, transport unit required, and patient dispatch time. The card victims then were allowed to be transferred to the assigned counters in the hall representing the hospitals and treatment areas, but only after the blanks on the back of each card holding the treatment information detailed above had been filled in. Each incident site and treatment area had a moderator to ensure that participants followed the exercise rules.

After completion of the exercise, the data on the cards were reviewed and compared to the predetermined triage category, required medical interventions, and hospital destinations. Card victims were considered to have been treated adequately if no major and less than 2 minor medical interventions were missed during the exercises. Major medical interventions were defined as procedures that could relieve the patient from life-threatening, limb-threatening, or any other severe morbid status. Meanwhile, for category IV card victims, providing no unnecessary resuscitation was regarded as adequate medical intervention. Notably, a victim disposition record kept during the exercises was reviewed. The dispositions or hospital destinations of dispatched card victims were justified as correct when all moderators showed agreement. The outcome measurements of the exercises were the mean accuracy rate of victim triage, medical interventions, and final disposition of the card victims.

Data analysis

One-way ANOVA analyses were applied for multiple proportional comparisons among the 4 triage categories. Tukey's post-hoc test was used for inter-group comparisons. Statistical calculations were performed with SPSS 10.0. Statistical significance was defined as p values < 0.05.

RESULTS

Table 1 lists the background of the participants in both exercises. Most participants were EMTs from either the County Fire Department or Airport Authority. Meanwhile, most team members of local DMAT were hospital physicians and nurses. Each exercise also involved 2 administrative staff from the Bureau of Health. Table 2 lists the roles assumed by the participants in the exercises. Participants were asked to play the roles of all types of responders in LDMS and some personnel from outside. Most participants played the roles they assumed in their daily jobs in the exercises, except for some EMTs who pretended to be team members of site medical teams.

Overall about 92% of the 400 card victims were correctly triaged in the exercises; about 2.5% of victims were under-triaged, leaving a 5.6% over-triage rate (Table 3). Moreover, around 86% of all card victims received adequate medical interventions (RAMI), and 88% had a correct disposition. Triage category IV victims represented the highest proportion of victims receiving adequate medical interventions, and 97.5% were triaged and had a correct disposition. The mean over-triage rate for category IV card victims was 2.5%. The statistical significance of this group differed from other categories in which a high proportion of victims had a correct disposition compared to category II and III card victims (97.5%, $p=0.009$) and RAMI compared with category II (97.5%, $p=0.039$).

Category II card victims had the lowest proportion of victims correctly triaged, with a 13.3% mean over-triage rate and a 3.19% mean under-triage rate. Statistically significant differences among various levels of triaging were noted between category II card victims and other categories, except for the over-triage rate between category III, and the under-triage rate between category I. This group also had

Table 1. Background of Participants in the Two Tabletop Exercises

	No. of participants	
	Exercise 1	Exercise 2
Emergency medical technicians (EMTs)	16	18
Hospital physicians	7	6
Hospital nurses	15	16
Administration staff of from the Bureau of Health	2	2
Total	40	42

Table 2. Roles Assumed by Participants in the 2 Tabletop Exercises

	No. of participants	
	Exercise 1	Exercise 2
Local resources		
Emergency joint command office executives	2	2
Dispatchers of a central dispatch center	2	2
EOC command staff	2	2
Emergency medical technicians (EMTs)	12	12
Local DMAT team members	12	14
Site medical team (SMT) members from hospitals	4	4
Outside resources		
EMTs	2	2
DMAT team members	2	2
SMT team members	2	2
Total	40	42

Table 3. Main Outcome Measurements of the 2 Exercises:
Mean Accuracy Rate of Triage Categories, Medical Interventions, and Final Disposition of Card Victims

Triage categories	I	II	III	IV	Total	*p*	Tukey's post-hoc test
No of card victims (n)	65	94	201	40	400		
Mean (%) card victims triaged correctly (SD)	93.08 (±1.09)	83.51 (±2.26)	93.53 (±7.07)	97.50 (±3.54)	91.91 (±5.74)	0.013	I > II III > II IV > II
Mean (%) of over-triaged card victims (SD)	0	13.30 (±2.26)	6.47 (±0.70)	2.50 (±3.54)	5.57 (±5.61)	0.012	II > I II >IV
Mean (%) of under-triaged card victims (SD)	6.92 (±1.09)	3.19 (±0)	0	0	2.53 (±3.08)	0.001	I > II I > III I > IV II > III II > IV
Mean (%) of card victims with a correct disposition (SD)	89.23 (±2.18)	82.45 (±7.57)	83.09 (±2.11)	97.50 (±3.54)	88.07 (±6.72)	0.009	IV > II IV > III
Mean (%) of RAMI card victims (SD)	85.39 (±1.08)	80.32 (±5.26)	81.10 (±4.93)	97.50 (±3.54)	86.08 (±8.00)	0.039	IV > II

Abbreviations: RAMI: received adequate medical interventions.

the lowest proportion of victims receiving appropriate management, specifically, 80.32% were RAMI and 82.45% received the correct disposition. Notably, category I and III victims displayed similar outcome measurement results in the exercises, namely, accurate triaging rates (93.53% vs. 93.08%), accurate disposal rates (83.09% vs. 89.23%), and proportions of victims who were RAMI (81.10% vs. 85.39%). There was a 6.5% mean over-triage rate for category III card victims, and among this group, no victim was under-triaged compared to 6.9% of category I card victims who were. The last card victim was dispatched to a treatment area or hospital within 45 min in both exercises.

DISCUSSION

Most experts classify disasters as damaging natural or human-caused events that mandate the mobilization of outside resources.(10) This definition of a disaster can be misleading in that it suggests that it is unreliable to depend on the local medical response system of the affected area. On the contrary, an effective local disaster response is the key to the immediate disaster response.(6,11) Speed and coherence of the local medical system are essential. Actually, a rapid and effective LDMS maximizes the chances of survival among disaster victims.(12)

Past earthquake epidemiology studies have revealed that the demand for emergency medical needs is strongest within 3 days of the shock.(13,14) In Western or developed countries, disasters affecting urban or suburban areas may even exhibit a still shorter emergency medical demand period, as most initial survivors are ambulatory and quickly arrive at hospitals.(15) Urban hospitals receive 50% to 80% of all patients with earthquake-related injuries during the first 24 hours in both Japan and Taiwan's experience.(16,17) Obviously, emergency medical needs can only be addressed at the local level, even for a disasters involving large-scale casualties.(18)

The basic management philosophy of the LDMS encompasses the introduction of outside medical resources, the evacuation of victims from the affected area, and the enhancement of definite medical care capacity.(19) The limited resource capacity of the LDMS more greatly hinders the achievement of the first 2 response strategies mentioned above than it does providing definite medical care, particularly during the critical first 12 hours.(20) We believe that a discrepancy exists between the limited manpower of the LDMS and the huge medical needs following a disaster. However, lessons learned from past experiences of ineffective medical responses to disasters are that most problems result from poor organization of the initial response. Improper assessment, a poor command system, and unsuccessful communications management are the 3 major contributors to this problem.[21] In fact, the early failure of an LDMS is not solely a problem of an insufficient response capacity. Around 50 medical teams with more than 500 medical personnel were mobilized and reached the affected area of Taiwan's Chi-Chi Earthquake within the first 12 hours.[22] Moreover, extensive outside resources are often available after 24 hours.[15] Unfortunately, the arrival of these aid groups is generally poorly coordinated, and less-damaged areas with viable road transportation and communications attract the bulk of the resources.[23] Therefore, the top priority mission of the new model of LDMS highlights the importance of good organization of the initial response actions. To accomplish these goals cost-effectively, 2 critical strategies are applied. Firstly, an EMRS is adopted as the basic structure of the LDMS. Secondarily, the policies and operation concepts of the LDMS must ensure appropriate assessments, an effective command system, and viable communications especially during the initial phase of the medical response. All local medical agencies such as the DMAT are responsible for executing this strategy.

Most departments of local governments do not have the resources to respond to a mass-casualty disaster on their own, and they will require assistance from other agencies. The size of the entity and a lack of funds for maintaining people and equipment that will only be used in a large-scale event contribute to this problem. The importance of EMS involvement in the local disaster medical planning process cannot be overemphasized. Early and active involvement of emergency medical care elements in developing these plans is imperative.[24] Therefore, it seems affordable and reasonable to adopt the EMRS model for the basic structure of the LDMS. The EMRS is a well-established structure in most county governments in Taiwan and has been subsidized by the central government for many years. It can effectively interface with the EMS, government health departments, and medical facilities. Most EMRS in Taiwan have their own radio communications system and have developed daily operational protocols. In addition, the EMRS is also designated to handle MCI, and its responders are trained to fulfill this mission. Past experiences demonstrated that an EMRS can be promptly activated in an MCI medical response. Flexible and rapid expansion of its functions allows EMRS to play dual roles in both ordinary medical emergencies and disasters. In developed and some developing countries, which have relatively disaster-resistant environments and good medical resources, EMRS survives a disaster better than those in underdeveloped countries.[7,25]

A DMAT is usually organized to function as a unit providing trauma life support or primary medical services.[26] Based on our strategies, the role played by local DMAT in our new LDMS model is more like that of a pioneer survey and command team. Consequently, the DMAT might be separated into small medical operational units, even at the expense of reducing their medical treatment capacity. The advantages of a structure comprising multiple small operational units include easy organization, rapid mobilization, accessibility to multiple locations, and less demand on hospital manpower.

The tabletop exercises demonstrated good teamwork performance by responders. Although the exercises simulated only the initial phase of the disaster medical response, they still proved the feasibility of the system design, including policies, operational concepts, and initial response actions. The mean under-triage rate was 2.5% in our tabletop exercises, and acceptable under-triage rates have been defined as 5% or less.[9] This highly accurate triage rate demonstrates that responders can apply the triage method quite well and indirectly ensures better field medical need assessment. Over 88% of victims experienced an appropriate disposition, demonstrating the effective and complex interactions among sites and treatment areas. The high accuracy of card victim management given a tightly constrained time schedule should be interpreted as a result of successful training and the competence of individual participants.

Among the 4 different triage categories, making a correct management decision was hardest for category II card victims. The victims of this group were more commonly over-triaged. Medical responders require further training to treat these patients. Victims with injuries at both ends of the severity scale can be sorted more easily, especially triage category IV victims. However, there was still a substantial proportion of category I card victims which were under-triaged. The cause of this relative high under-triage rate (6.9%) may have been due to limitations of the disaster triage system and ineffective application of the system by the triage personnel. No triage system is perfect, and triage sensitivity in identifying patients needing critical care interventions have limitations especially for disaster triage methods which seriously consider resource management.[9] Triage personnel are told to sacrifice some portion of victims with minimal chances of survival when they acknowledge the limited capacity of definite medical care. Among the under-triaged category I card victims in the exercises, 22% of them were triaged as category IV, and it is reasonable to believe that this may have been a medical resource consideration. Although it was not statistically significant, the outcome measurement results of the exercises showed that it was easier to make correct decisions regarding the disposition and triage of victims than it was to provide medical interventions. The percentage of victims receiving adequate medical intervention is expected to be further reduced in an actual disaster, while the former 2 indicators are expected to show smaller decreases. In the 1995 Hanshin earthquake, Japan, the first peak in medical demand was 2-8 hours after the disaster, and the medical treatment capacity was significantly reduced due to damaged medical facilities or shortages of medical staff and equipment. In the affected area, 2.3% of hospitals had completely collapsed, and 6.9% had partially collapsed.[27] However, 1/3 of the seriously injured patients could be successfully sorted out and dispatched to the non-affected hospitals. This greatly reduced mortality.[17]

The new LDMS model of Taoyuan County provides a new template for a basic disaster medical response system for Taiwanese county governments. If the new LDMS model is implemented in Taiwan, it may merit the attention of disaster experts from around the world. A high probability exists that these experts will be able to witness how an experimental system for organizing medical disaster responses will be challenged by a real disaster in the near future.

Simulation models including act-out, talk-through, tabletop exercises and computer software programs are valuable for planning, training, and evaluating disaster response systems.[28] Full-scale act-out exercises bring a concrete scenario to life, but have tremendous financial and manpower costs. Changing variable situations can be accepted when they are carried through talk-through or tabletop exercises. Talk-through exercises are designed for those who have to make decisions, while tabletop exercises can be used for all levels of medical responders.[29] Computer software programs can simulate large-scale disasters, and variables can be input into the program. They can predict the number of casualties and can assess the response of a regional health-care system during the immediate post-disaster period.[30] However, a computer software program was not applied to test the new model because it does not include participation of individuals trained to respond to actual disasters, nor does it consider human factors of these medical responders. Human factors of medical responders are a major determinant of a successful medical response. Even well-trained medical responders act inappropriately and deviate from carefully designed plans in responding to actual disaster situations.[31] This study used tabletop exercises because they allow the participation of multiple medical responders and thus variable human factors of individual responders can be included in evaluating the medical response. Overall, tabletop exercises provide increased realism, and thus the system design, training, and human factors can be evaluated. In addition, tabletop exercises provide a cost-effective method of simulating large-scale disasters that is easy to monitor and control.

The tabletop exercises conducted in this study were limited by the over-simplification of some of the procedures, roles, and materials required for disaster medical responses. For example, the exercises did not consider probable damage to transportation routes and consequent shortages of necessary equipment.

Furthermore, the evaluation, treatment, and transportation of real patients are significantly more complicated and time-consuming than considered herein. The scale of the scenario and number of participants were also small. Patient dispatch and transportation times were also not seriously considered. Additionally, the major outcome measurements of the exercises were not the optimal indicators for evaluating the overall system response. The outcome measurements of the exercises should be considered semi-quantitative results, showing the performance of responders in key initial casualty handling procedures when applying the proposed LDMS model. More-comprehensive simulation methods are required to evaluate disaster response systems. "War games" computer software simulation models through the Internet allowing the participation of multiple respondents may also be a new promising method for future investigations.

In summary, this study found that an EMRS-oriented LDMS model can respond quickly, efficiently, and adequately during the initial phase of a disaster in tabletop exercises. The key mission of an LDMS should be good organization of the initial response actions. Moreover, a local DMAT can be deployed in small separate units as survey and command teams. Further clinical investigations are required to prove the efficacy of the new LDMS model in real disasters or full-scale drills.

Acknowledgments

The authors gratefully acknowledge the valuable assistance and support from Ms. Hsiu Shih, Third Section Chief, and Kun-Yu Chao MD, MPH, Director of the Bureau of Health of Taoyuan County, for organizing the panel meetings. We also thank Shu-Ping Tseng, Chief of the EMS section of Taoyuan County's Fire Department for distinguished contributions. This research was supported as a governmental scientific research project (DOH90-TD-1045A) with financial support from the Department of Health, Taiwan.

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以沙盤推演方式測試地區災難醫療應變體系的訓練新模式

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背 景：政府災難醫療應變體發展計劃中，專家小組建議地方政府以地區平常運作的緊急醫療系統來作爲地區災難醫療應變體系的基本架構，並發展出新的運作模式，我們以沙盤推演方式評估新訓練模式的地區災難醫療應變體系的可行性與效能。

方 法：演習舉行前，對災難醫療應變人員施以訓練，以確定能充分了解地區災難醫療應變體系的新運作模式，訓練結束後，共有40與42位人員分別參與二次沙盤推演，演習模擬地震在六個不同事故地點產生共400名傷病患，演習以對病患檢傷、決定去向與治療正確率作爲測試的結果指標。

結 果：在兩次演習中，平均92%模擬病患被正確檢傷、88%被正確決定去向、約86%病患被正確治療，且所有病患都在演習開始45分鐘內被送至合適治療場所。

結 論：在沙盤推演演習中，以地區緊急醫療系統模式架構的災難醫療應變體系對災難能快速、有效地做出充分醫療應變。
(長庚醫誌 2003;26:879-88)

關鍵字：緊急醫療救護系統，大量傷患事故，災難，災難計劃。

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受文日期：民國91年12月18日；接受刊載：民國92年7 月11日。
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