STUDY AND DEVELOPMENT OF THE RESCUE ROBOT PREVENTING CRUSH SYNDROME OF EARTHQUAKE VICTIMS

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Keywords: Disaster, Earthquake, Rescue robot, Crush syndrome.

Abstract: In the Hanshin and Chu-etsu earthquake, many victims were crushed by rubble and died by "crush syndrome". Even the simple rescue method that remove the rubble, it could be a cause of death. As the only countermeasure, DMAT (=Disaster Medical Assistance Team) creeps into fallen houses, and treat dialysis or drip "crush injury cocktail". But these methods are very dangerous for victims and DMAT to treat amid the aftershocks. We think that Rescue Robot technique is just suitable solution for the dilemma under various and dangerous situations. The Rescue Robot has the dual tiered crawler. The Rescue Robot goes through under rubble open, and the victims are held in the container inside of the Robot body. We already built a prototype model, so we present an outline of our rescue robot. And we will show the research of the Blade mechanism to open rubble, and the mechanism of prevent Crush Syndrome that will be mounted on 1/1 size prototype model in the future.

1 INTRODUCTION

Japan has 0.25 percent of global land in the world. Compared to it, the frequency of earthquakes above magnitude 6 is 20.8 percent (see Figure 1), and the number of active volcanoes is 7.0 percent compared with the world total.

Japan is a small country, but there has the most frequent earthquake.

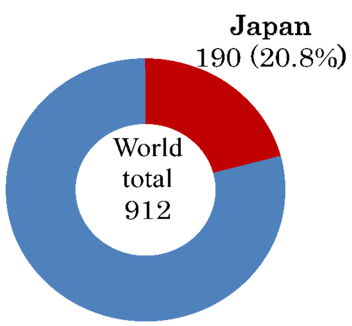

Figure 1: Number of earthquakes above magnitude 6. (Copied from Homepage of Japanese Cabinet Office http://www.bousai.go.jp/1info/pdf/saigaipanf.pdf).

1.1 Problem with Current Disaster Medical Engineering (ME) in Japan

Professor Fukumoto of Nagaoka University of Technology, who was performed disaster medical treatment at 2004 Chu-etsu earthquake and 2007 Chu-etsu offshore earthquake in Japan. He got a shock because disaster ME was not progressed since Great Hanshin earthquake 1995. In shelter, medicines, water and electricity were not enough supplied for several days cause of lifeline damage. Almost medical equipments were broken by falling on the floor or/and power failure, and the run out of manpower caused by many patients rushing to an Alternative Medical Treatment Site at the same time. The doctor was not able to take even a short break for 4 days.

If this situation was ignored, the likelihood of medical negligence of doctors increases, and decrease doctors who voluntarily treat in a disaster time

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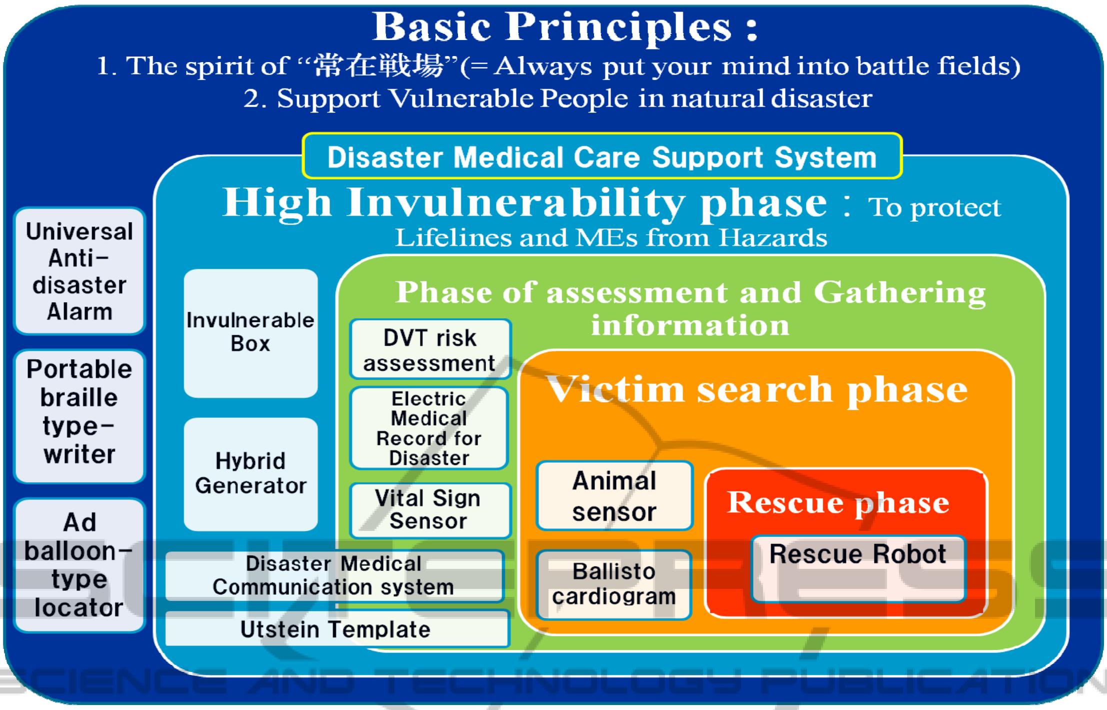

Figure 2: Outline of the Disaster Medical Assistance System.

1.2 The Disaster Medical Assistance System

To solve these problems, we, "The Disaster ME laboratory" are aiming to construct "the Disaster Medical Assistance System" (see Figure 2) which has been designed to support disaster medical care through medical engineering that based on bitter experiences of these earthquakes.

Devices of "the Disaster Medical Assistance System" have correlations with each other in terms of by functioning systematically and dealing with various disaster situations.

The Rescue Robot is one of the devices of the Disaster Medical Assistance System. It is belonging to the center of this system that was defined as "Rescue phase".

In other words, this rescue robot is not intended to operate alone. This Robot will be able to work only after embedding this system.

2 THE RESCUE ROBOT

We will introduce "The dual crawler-type Rescue Robot" to prevent crush syndrome.

Figure 3 is the picture in which prototype model of the robot was demonstrated in "the safe and secure festival in Yokohama 2009".

Figure 3: Appearance of the Rescue Robot.

2.1 Necessity of the Rescue Robot

In the Hanshin and Chu-etsu earthquake, many victims crushed by rubble. But many victims died by symptom of "crush syndrome", too. Even the simple rescue method that remove the rubble, it could be a cause of death.

As the only countermeasure, Disaster medical assistance team (DMAT) creeps into fallen houses, and perform confined space medicine (CMS) that treat dialysis or administration of intravenous fluids at present.

These methods are too dangerous to treat amid the aftershocks for both victims and DMAT.

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Nonetheless, it is problem that cannot begin the rescue operation until safety is secured.

We think that the rescue robot technique is just suitable solution for the dilemma under various and dangerous situations.

2.2 Crush Syndrome

Crush syndrome is a form of traumatic rhabdomyolysis (= a condition in which damaged skeletal muscle tissue breaks down rapidly) that occurs after prolonged continuous pressure and characterized by systemic involvement.

Extensive muscle crush injury culminating in the crush syndrome is often lethal unless promptly and vigorously treated.

The damages are seen after a prolonged period of pressure on a muscle group. The pressure causes necrosis of the muscle, and during revascularisation, diffusion of calcium, sodium, and water into the damaged muscle cells is seen, together with loss of potassium, phosphate, lactic acid, myoglobin, and creatinine kinase. These changes can lead to hyperkalemia (= medical emergency due to the risk of potentially fatal abnormal heart rhythms), acidosis (=an increased acidity in the blood), acute renal failure, and hypovolemic shock (= cause of lack of blood).

Crush syndrome is commonly encountered after earthquakes, and in various other disasters.

Sudden release of a crushed extremity may result in "reperfusion syndrome" (= acute hypovolemia and metabolic abnormalities). This condition may cause lethal cardiac arrhythmias. Further, the sudden release of toxins from necrotic muscle into the circulatory system leads to myoglobinuria (= the presence of myoglobin in the urine), which causes renal failure if untreated.

Difficulties with communication and transportation in the disaster often prevent early rescue and treatment. Early rescue and administration of intravenous fluids are important in preventing renal failure.

2.3 Advantage of the Rescue Robot

2.3.1 Strong Point of our Crawler System

We wanted to make the Rescue robot that can work under rubble. But, we could not adopt existing crawler mechanism.

Existing crawler robots are too hard to proceed under rubble. Because the crawler has problem with rotational direction. The problem is that they are lodged in narrow space vertically (see Figure 4).

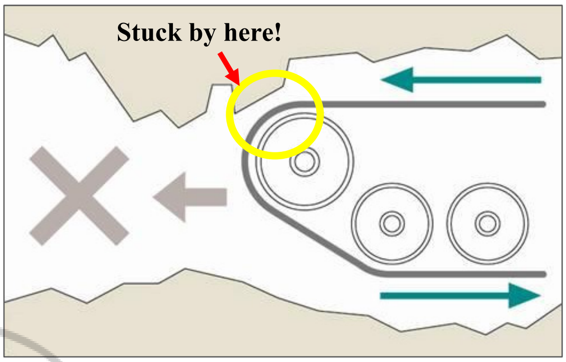

Figure 4: Problem of existing crawlers.

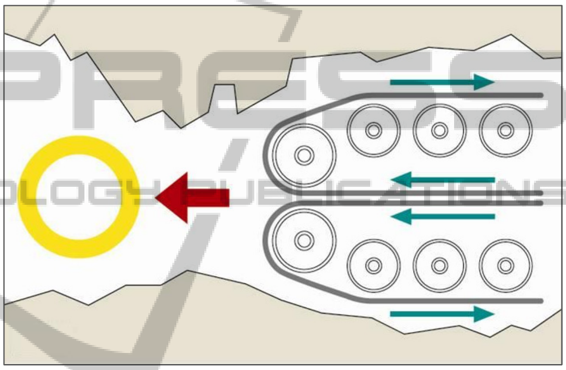

Figure 5: Advantage of our crawler system.

Therefore, we thought out the dual tiered crawler that coupled with crawler runs adverse directions. This crawler system could grip obstructions above, and it was also possible to even use as foothold (see Figure 5).

2.3.2 Mechanism of the Crush Syndrome Prevention

As "2.1 Necessary of Rescue Robot", if the Rescue Robot could reach at the victim under rubble, the victim would occur Crush syndrome cause of just only way to remove rubble.

Therefore, we designed "the mechanism of the Crush syndrome prevention".

The Rescue Robot is equipped with the cuff into that body. The cuff is inflatable band used in sphygmomanometer (= blood pressure meter).

The cuff is inflated rapidly by using carbon dioxide gas from small-sized cylinder. It is able to stop blood flow around affected part (mostly leg) by inflate cuff pressure. In other words, this cuff works to prevent re-circulating of blood that cause contamination, which prevents the Crash syndrome.

This method is only a first–aid treatment, it is necessary to treatment minutely by doctor after the rescue.

In addition, there is no practical example of this approach, it will require further research and experimentation.

2.3.3 Vital Sign Sensor Probe

Procedure of Crush syndrome prevention is a medical practice. Therefore, measurement of vital signs is essential.

The Vital Sign Sensor Probe is composed of Near Infrared Camera, Infrared LED Light and Microphone/Speaker. These Sensors are equipped with tip of the flexible arm.

The Near Infrared Camera and the Light checks the victim status and blood flow measurement visually. The Microphone is used to determine responsiveness of victims and check their heartbeat. The Speaker is used to call the victim and give their encouragement. (see Figure 6)

The doctor and operator utilize them for determining the severity of the victims.

Because hemoglobin absorbs near infrared light (wavelengths about 780nm), we can confirm superficial veins and the flow.

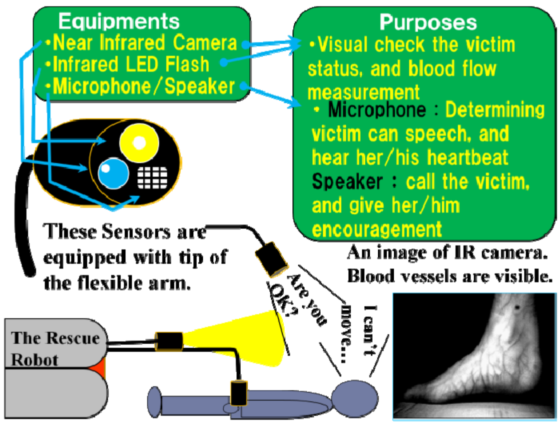

Figure 6: Outline of the Vital Sign Sensor Probe.

2.4 Expected Procedures of the Rescue Operation

First, the Rescue Robot is operated by three peoples and more. As the detail of the member's professions and rolls, Emergency Medical Technician (EMT) as operator, Firefighters (or any can operate) as cable management assistant, and doctor who performed the operation instructions (see Figure 7). This selection was designed based on the laws of Japan.

This Robot can be controlled remotely by wired control panel. It goes through under rubble with squeezing rubble and reached to victim (see Figure 8). After removal of rubble, affected parts of victims are tighten smoothly by cuff to prevent crush syndrome. And the victim is picked up in the container inside of the Robot body. (see Figure 9).

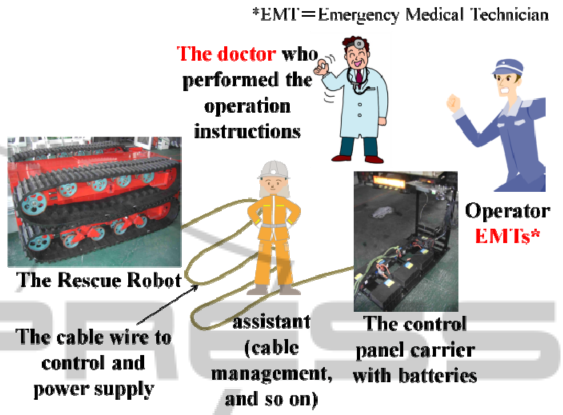

Figure 7: Expected operators of the Rescue Robot.

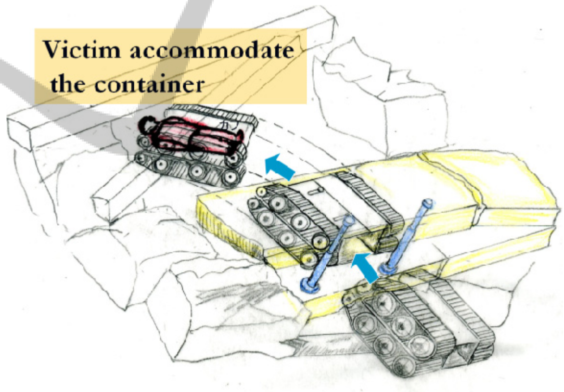

Figure 8: Assumed figure of the Rescue Robot Operation.

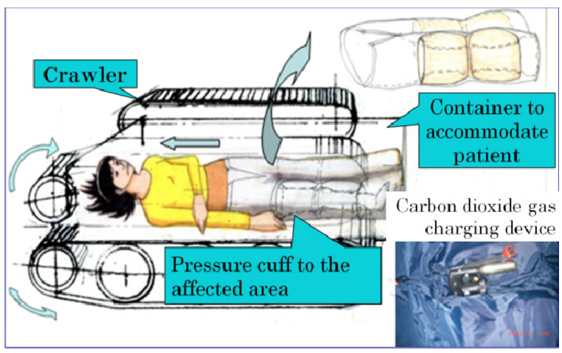

Figure 9: Assumed figure of putted on the cuff.

After picking up the victim in the container, the Rescue Robot goes back from under rubble to

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ground. In the safe place to both victims and rescuers, after that the victims are took enough treatment by doctors.

2.5 Specification of the Rescue Robot

The following are the specs of 1/1-sized prototype model of the Rescue Robot that currently under development. Incidentally, all of figures do not include the figure of "the Blade mechanism to open rubble" and "the mechanism of the Crush syndrome prevention" that cannot be installed to the Rescue Robot currently.

Length: 1.92m

Width: 1.33m

Height: 0.76m

Weight: 329kg (Only the vehicle weight. Not include control panel's and cable's)

Engines: 2 motors of CVVF (Constant-Voltage Variable-Frequency) control drive

Batteries: DC12V × 6 = 72V (see Figure 10)

Controls: Using the remote control panel connected by 10 meters cable wire (Batteries are mounted on control panel carrier)

Sensors: Front and Rear Cameras (and considering mount a roof top camera), the Vital Sign Sensor (made by Near Infrared Camera, Microphone / Speaker and LED Light)

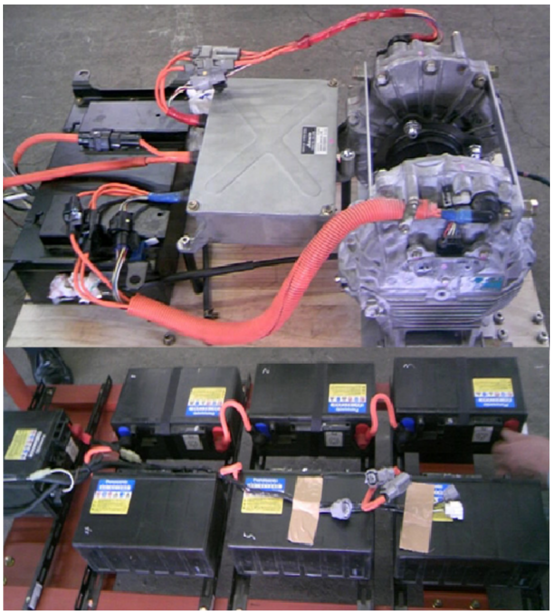

Figure 10: Motors and Batteries.

3 ISSUES OF THE RESCUE ROBOT

3.1 Current Issues

Various problems arise in disaster time, but this prototype may be able to withstand these situations. Introduce of the following improvements to the Robot enable the handling of various situations from now on.

1) Improvement of the anti-crush durability of whole parts including container and crawler.

2) Waterproof and fireproof.

3) Study and development of the Blade mechanism to open rubble.

4) Improvement of the victim accommodation mechanism.

5) Improvement of the mechanism of prevents Crush Syndrome.

6) Improve maneuverability.

7) Improve Safety.

Importantly, 3), 4), 5), and these quick and smooth cooperation are very important to rescue victims.

3.2 Present Status of the Blade Mechanism to Open Rubble

The first prototype of the Rescue Robot is not mounted on this blade mechanism. Because we intended that the Robot will action to collapsed Japanese-style one-story houses. These are the most collapsed building in past Japanese earthquakes. But collapsed Japanese houses still have roofs in many cases (see Figure 11). So we have supposed that can lift and go through under the roof, it is enough for the crawler only.

Figure 11: Collapsed Japanese-style house by Chu-etsu earthquake.

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However, we found that it is need to lift objects smaller than roofs, now we designing to the Blade mechanism make use of 1/5 sized model. Figure 12 is one of the proposed designs

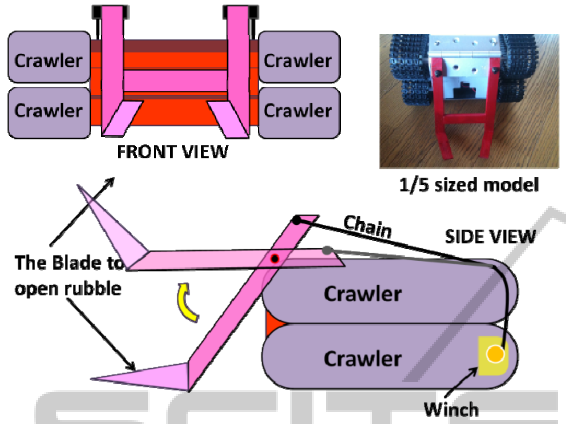

Figure 12: Proposed design of the Blade mechanism.

3.3 Present Status of the Mechanism to Prevent Crush Syndrome

This mechanism is necessary to directly touch the living human body, it is requires a very delicate design. For example, the disaster scene severity, victim's body position, place of the affected area, and so on.

Figure 13 is the latest proposed design of the mechanism to prevent Crush syndrome.

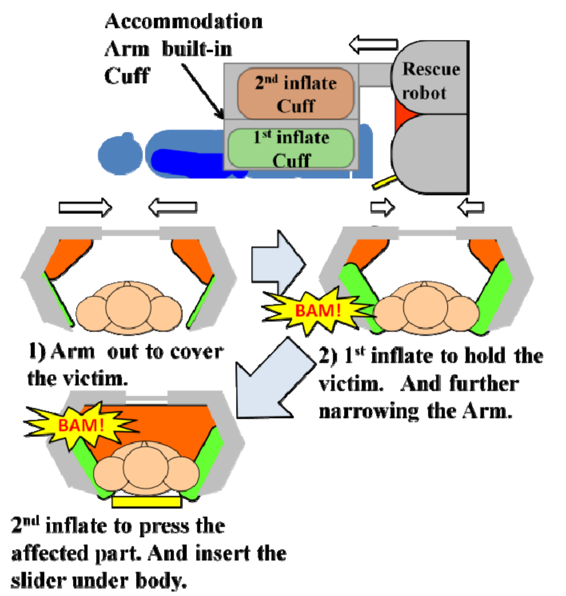

Figure 13: Proposed design and its procedures of "Two-step inflates method".

The advantage of this method will not have to touch the victim directly by the mechanical arm. And it can make the mechanism simply, and thus it can be expected to improve reliability.

However, we will have to conduct a detailed examination, including the shape of Cuff that can prevent Crush syndrome effectively or not.

In the future, we will produce the new design mechanism experimentally, after mechanical tests, give medical tests.

4 CONCLUSIONS

In this study, we produce the first 1/1 sized prototype model.

In the future, we are planning to make mechanical improvements using 1/5 and 1/1 sized models. At the same time, we will start to make medical tests (top priority is Crush syndrome) using 1/1 sized prototype.

But many issues still remain to perform medical tests before.

This robot was born from the needs of experience in an actual disaster medicine. In order to prepare for next big earthquake, we will do the research and development as soon as possible.

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REFERENCES

Tadokoro, S., 2010. 28(2), 134-137. *Journal of the Robotic Society of Japan*. The Robotic Society of Japan.

Sahashi, T., Sahshi, A., Uchiyama, H., Fukumoto, I., 2010. 212. Program Book of 10th APCDM. *The 10th Asia Pacific Conference on Disaster medicine.*

Fukumoto, I., 2010. OS-2-2. Program &Abstracts Book (DVD). *Conference of Japanese Society for Medical and Biological Engineering.*

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Sahashi, A., Sahashi, T., Uchiyama, H., Fukumoto, I., 2010. 3-4. *Proceedings of the 29th JSMBE Kou-Shin-Etsu Branch Conference 2010*. Japanese Society for Medical Biological Engineering.

Sahashi, T., Sahshi, A., Uchiyama, H., Fukumoto, I., 2010. 3G1-7. *Proceeding of the Robotic Society of Japan (DVD)*. The Robotic Society of Japan.

Tsuchiya, S., Tatano, H., Okada, N., 2008. (10), 355-364. *Proceeding of Institute of Social Safety Science*. Institute of Social Safety Science.

Sahashi, T., Sahshi, A., Uchiyama, H., Fukumoto, I., 2009. Program Book of 9th APCDM. *The 9th Asia Pacific Conference on Disaster medicine.*

Fukumoto, I., 2008. 13(2). 218-225. *Japanese Journal of Disaster Medicine*. Japanese Association for Disaster Medicine.

Higuchi, N., 2008. 63(3), 382-384. *Japanese Journal of Radiological Technology*. Japanese Society of Radiological Technology.

Mahoney, E, L., Whiteside, F, D., Belue, E., Mortisugu, P, Kenneth., Esch, H, V., 1987. 16(3), 354-358. Annals of Emergency Medicine. *Journal of the American College of Emergency Physicians*. The American College of Emergency Physicians.

Ensaria, C., Tüfekçioglub, O., Aylia, D., Gümüsc, T., Izdesc, S., Turanlid, S., 2002. 92(4), 941–943. *Nephron journals*. Karger AG.

Greaves, I., Porter, K,M., 2004. 12(1), 47-52. *Accident and Emergency Nursing*. Elsevier Ltd.

Demirkiran, O., Dikmen, Y., Utku, T., Urkmez, S., 2003. 20, 247-250. *Emergency Medicine Journal*. BMJ Publishing Group Ltd.

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