

Rescue Lifting System (RLS) Might Help to Prevent Death After Rescue from Immersion in Cold Water

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Objective: In order to prevent sudden death after rescue from immersion in cold water, victims should be handled carefully avoiding additional cardiovascular stress. In this study we investigated if a new double-sling rescue system ("Rescue Lifting System"-RLS) was superior to conventional single-sling techniques. **Methods:** We studied 14 healthy male subjects in good physical condition aged 21 to 40 years. They were lifted up from the ground with the new RLS and two conventional techniques ("Lifesling" and a navy rescue system used in SAR helicopters). Heart rate was determined by QRS detection (Polar Precision Performance device; Polar Electro Oy, Kempele, Finland) and blood pressure by sphygmomanometry. RLS and "Lifesling" were tested under conditions of dry land and immersion in 18 °C water. **Results:** Rescue with RLS induced only moderate heart rate changes which were significantly lower (about 30 bpm) than with conventional techniques. These findings could be reproduced under "wet" condition. **Discussion:** RLS enables rescue in a supine position avoiding extensive orthostatic stress. It might therefore be favourable in preventing sudden death after rescue from immersion in cold water.

Key words: Rescue Lifting System, circum-rescue death, immersion, rescue, water sports.

Introduction

Sudden death after rescue from immersion in cold water may occur [3, 4]. It is well known that some people die from hypothermia even though they are uninjured when rescued. The explanation may be that this is due to ventricular fibrillation resulting from the afterdrop of core temperature precipitated by rough handling during rescue [8]. The pathophysiology of cold

water immersion hypothermia is complex affecting virtually every body system [5]. As far as cardiovascular function is concerned, there is an early catecholamine-mediated increase in heart rate, cardiac output, and mean arterial pressure [5]. Subsequently the arterial pressure remains elevated, resulting in a reflex decline in heart rate and cardiac output which leads to hypotension [5]. The negative inotropic and chronotropic effects and decreased effective blood volume have further deleterious effects on cardiac output [5]. This leads to an alternative hypothesis claiming that most deaths after rescue occur through an imbalance between the active vascular capacity and the circulating fluid volume, i.e. relative hypovolemia or fluid overload [8].

Regardless of the possible cause of circum-rescue death it is generally accepted that these patients should be evacuated carefully avoiding additional cardiovascular stress [5]. Even minor manipulations can induce ventricular fibrillation in a hypothermic patient. Therefore rough handling of the patient must be avoided, and transport has to be accomplished as gently as possible with the patient in a supine position [1, 2, 10]. In practice there are two ways of rescue: by helicopter or by boat, using single-sling rescue equipments like the "Lifesling" system in yachting. "Lifesling" is a floating harness attached to a line secured to the boat and is kept in a box mounted to the stern rail. It is thrown out when approaching the person in the water. The victim can then be brought onboard by attaching the line to a halyard and winching the subject up over the lifelines. A very similar device is used in helicopter rescue consisting of a single sling, too. Usually helicopter staff help the victim into the sling and attach the person securely before the patient can be winched up to the aircraft. It has to be considered that both techniques do not enable the rescue of a patient in a supine position as suggested by several studies [1, 2, 10].

We know from the literature that orthostatic stress may induce huge cardiovascular responses, especially in ill or severely stressed subjects precipitated by adrenal and corticosuprarenal hyperactivity [7]. These mechanisms play an important role in the rescue from immersion in water because the patient changes from a more or less supine (swimming in water) to an upright position (hanging in the sling). Furthermore, winching up a patient from the water induces discomfort or even pain, also leading to cardiovascular stress. [6, 11].

In summary, rescue from immersion in water leads to hemodynamic stress: Firstly, there is a redistribution of blood during immersion, attributed to the high density of water compared to air. This leads to an increase of cardiac output [5]. Being brought up from water, patients could experience inverted hemodynamic modifications with severe consequences. Secondly, orthostasis may impair the hemodynamic status [7], and thirdly, also pain may occur inducing hemodynamic stress. [6,11].

It was the aim of the present study to evaluate a new double-sling system ("Rescue Lifting System" – RLS, developed by M. Schwindt, University of Applied Sciences and Arts, Hildesheim, Germany) enabling rescue from water in a supine position. We were interested to know whether the RLS system was able to minimize cardiovascular changes which might compromise the patient's outcome and compared it to conventional rescue systems.

Materials and Methods

We studied 14 healthy male subjects aged 21 to 40 years (mean 26.6 years, SD = 5.1). All subjects were in good physical condition (mean PWC170 2.91, SD = 0.23) and of normal weight (mean weight 83.0 kg, SD = 7.6; mean height 184 cm, SD = 6.7). State and trait anxiety determined by STAI [15] revealed scores within normal range (mean of state anxiety 32.4, SD = 4.0; mean of trait anxiety 31.2, SD = 5.6). The experimental procedure and the types of slings used were explained to all participants. During the experiment subjects were not able to communicate with each other. This was done in order to exclude that the report of pain could influence anxiety levels and cardiovascular reactivity [13]. All subjects gave written informed consent to the experimental procedure.

Dry land condition

All subjects underwent a randomized sequence-controlled study design consisting of three trials: All participants were lifted from the ground (lying in a supine position) by three techniques:

1. The new double-sling "Rescue Lifting System" (RLS): Like "Lifesling" RLS is a floating harness attached to a line secured to the boat and is kept in a box mounted to the stern rail. It is thrown out, and the victim can then be brought on-board by attaching the line to a halyard and winching the subject up over the lifelines. In contrary to "Lifesling" RLS enables rescue from water in a supine position because one sling is placed around the thorax and the other around the thighs (Fig 1).
1. The "Lifesling" (West Marine, Watsonville, Ca., USA) which is used for rescue in yachting (described in the introduction section). This is a single-sling system which winches up victims floating on the water.
2. A slope used by the German Navy for SAR helicopters. This is a single-sling system like the "Lifesling". Usually the slope is applied by the rescue personnel of the helicopter (they jump out of the helicopter and help to attach it properly).

Five participants started with the "Lifesling", 5 with the RLS, and 4 with the navy system. The slings were applied by an experienced physician (German Navy). Subjects were asked to stay in each rescue system for about six minutes but many par-



Fig. 1 Rescue Lifting System applied to a participant of the study. One sling is placed around the thorax and the other around the thighs.

ticipants could not stand hanging in the „Lifesling“ for more than four minutes and broke off after about two minutes in the navy rescue system. Before and after this stressor subjects rested in a supine position for six minutes.

Immersion condition

Four months later subjects were asked to participate in a second phase of our experiment (rescue from immersion in water). At first the participants rested on dry land for 10 minutes (air temperature 21 °C), then they went into the water (water temperature 18 °C) and were asked to stay there floating (without extensive swimming movements) for 10 minutes. Afterwards, they were winched up using RLS or "Lifesling" (sequence-controlled, cross-over design, half of the subjects started with RLS, then the "Lifesling" was used, and *vice versa*). After hanging in the sling for 4 minutes they rested on dry land for additional 10 minutes.

Cardiovascular reactions under both conditions were recorded employing sphygmomanometrical blood pressure recordings every minute (six during rest, six during stress, and six during rest again). The cuff was inflated to a maximum pressure of 175 mmHg, deflation speed was 4 mmHg/s in order to control for cuff inflation hypertension [6,11]. Heart rate was measured with a Polar Precision Performance device (Polar Electro Oy, Kempele, Finland) working on the basis of QRS detection [14].

After each trial subjects were asked to rate pain and discomfort on a visual analogue scale [12] ranging from 0 (no pain or discomfort at all) to 10 (strongest pain and discomfort imaginable).

For statistical analyses t-tests for paired samples, one-way analyses of variance with post hoc least significant difference tests, and bivariate Pearson correlations were used.

Results

Regarding the dry land condition, heart rate measurements indicated no significant differences between the three groups when resting on dry land. However, heart rate markedly in-

creased when subjects were placed in the "Lifesling", RLS, and the navy system (Fig. 2). When the subjects were winched up, heart rate was significantly lower with RLS compared to the other techniques (RLS mean heart rate 81.9 beats per minute - bpm, SD = 13.7; „Lifesling“ 108.3 bpm, SD = 10.0; navy 110.4 bpm, SD = 9.3; $F = 27.9$, $p < 0.00001$). This means that heart rates with RLS were 26.4 bpm lower than with the "Lifesling" and even 28.5 bpm lower than with the navy rescue system.

Sphygmomanometrical blood pressure measurements could not be performed with the subjects hanging in "Lifesling" and navy rescue system since there was a compression of axillary artery and blood flow into the arms ceased. This was controlled by palpation of radial pulse.

In RLS no arterial compression occurred and systolic and diastolic blood pressure rose only slightly from rest to stress (systolic blood pressure + 12.4 mmHg, SD = 7.7, $p < 0.05$; diastolic blood pressure + 11.8 mmHg, SD = 9.0, $p < 0.05$).

Among the whole population rise of heart rate from rest to stress correlated significantly and positively with state anxiety ($r = 0.50$, $p = 0.001$), but not trait anxiety. PWC170 correlated negatively with increase of heart rate ($r = -0.75$, $p = 0.031$) indicating that subjects in good physical condition exhibited lower vulnerability to orthostatic stress.

After exposure to immersion in water, there was an increase of 15.8 bpm (SD = 15.0) when the subjects were winched up with the "Lifesling". When the RLS was used, heart rate even slightly decreased (-6.8 bpm, SD = 5.9), see Fig. 3. The changes were significantly different between RLS and "Lifesling" ($p = 0.001$).

Regarding the VAS, subjects evaluated the RLS to be better and found it more comfortable than the other rescue systems. RLS was scored with a mean of 3.4 points (SD = 3.4) after six minutes of stress, whereas "Lifesling" with 8.0 (SD = 2.0) after four minutes, and navy rescue system with a mean of 7.6 (SD = 2.3) points after two minutes hanging in the slings.

Discussion

Rescue from immersion in cold water is risky because of the danger of sudden death even in uninjured patients [3,4]. It is believed that rough handling of these patients during rescue might induce ventricular fibrillation resulting from the after-drop of core temperature [8]. Another pathophysiological correlate might be an imbalance between the active vascular capacity and the circulating fluid volume, i.e. relative hypovolaemia or fluid overload [5,8]. Regardless the possible cause of these fatal incidents it is generally accepted that cardiovascular stress induced by rough handling during rescue should be avoided [1,2,10].

In the present study we investigated if a new technique - the "Rescue Lifting System" (RLS) - might be favourable avoiding extensive cardiovascular stress during rescue from immersion in cold water. We know that orthostasis in lifting with straps is a potent stressor [9], especially in ill subjects [7]. Therefore single-sling rescue systems like "Lifesling" and helicopter rescue systems might be unacceptable because orthostasis poses a problem when using these techniques. We could demonstrate that during rescue with conventional systems heart rate

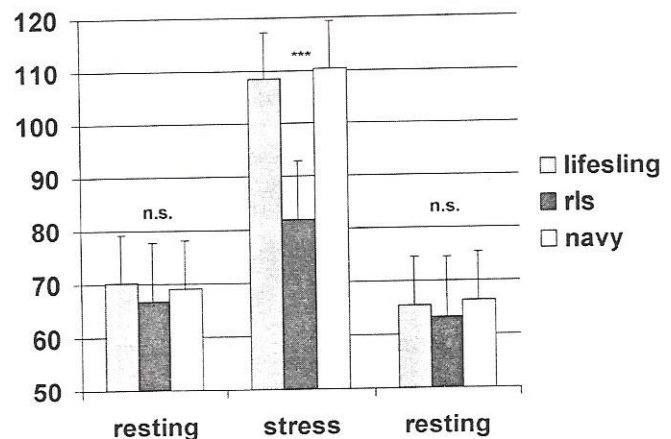


Fig. 2 Mean heart rates in beats/min during resting and stress period (hanging in the sling). *** $p < 0.00001$, n.s. = not significant.

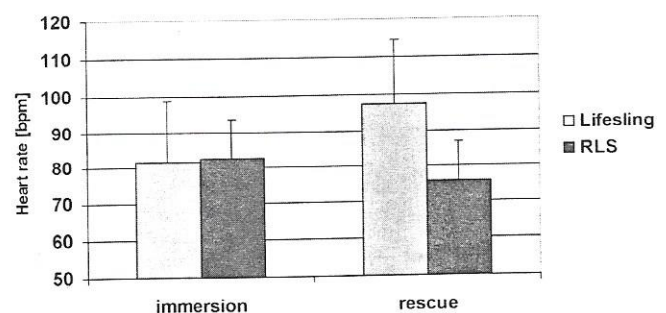


Fig. 3 Heart rate during immersion in water (floating) and winching up in "Lifesling" and RLS. The induced changes differ significantly between the two rescue techniques ($p = 0.001$).

markedly increased (for up to 40 bpm) indicating that immense cardiovascular stress was induced. In contrast rescue with RLS only induced moderate heart rate changes which were significantly lower (about 30 bpm) than with conventional techniques. Furthermore blood pressure exhibited only moderate changes during application of the RLS (systolic and diastolic increase of about 10 mmHg). Blood pressure could not be determined in "Lifesling" and helicopter technique because there was an arterial compression. When extrapolating our results to the cold water rescue situation, these findings could be reproduced. In summary, we believe that rescue with RLS induces only little cardiovascular stress because orthostasis can be avoided. Another explanation could be that the pain and discomfort induced by RLS was significantly lower. We know that pain is a potent stressor [6,11]. Thus avoidance of pain and discomfort might contribute to the positive results in our study.

Furthermore we found that anxiety levels correlated significantly with heart rate changes. This finding supports the results of former studies indicating that anxiety moderates cardiovascular reactivity [13].

Since extensive cardiovascular stress should be avoided in patients rescued from immersion in cold water, we believe that rescue with double-sling systems like RLS might be favourable and help to prevent sudden deaths. There are two reasons for

this hypothesis: On the one hand RLS avoids ortostatic stress, on the other hand it reduces pain and discomfort during rescue. In summary, we believe that the RLS offers an appropriate way to accomplish gentle rescue of patients from immersion in cold water. The results of our study indicate that new techniques for SAR helicopters enabling rescue in a supine position should be developed. Nevertheless, further studies are necessary to evaluate if the RLS may prevent or decrease fatal incidents after rescue from cold water in practice. However, our study supports the assumption of advantageous effects of double-sling systems.

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