

Application of the "G-Suit" to the Control of Hemorrhage in Massive Trauma

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THERE has been a recent resurgence of interest in the technic of external counterpressure to control intra-abdominal hemorrhage since it was first described by Crile¹ in 1903. The experimental reports of Ludwig⁸ and Gardner⁶ document the efficacy of external counterpressure in prolonging the survival time of dogs with surgically produced lacerations of the aorta. Similarly, Wangenstein¹¹ demonstrated the effectiveness of external counterpressure with surgically induced lacerations of extra-abdominal vessels. Gardner *et al.*^{5, 6} and others³ described the clinical use of external counterpressure by means of a commercially available "G-suit"[®] in the treatment of massive abdominal hemorrhage secondary to gynecologic catastrophes, ruptured abdominal aortic aneurysm, and other large vessel injuries. Crile² first suggested in 1906 that external counterpressure might be useful in the management of acute trauma, but as yet little attention has been given to this application of the "G-suit."

This report presents a brief clinical experience with the application of the "G-

suit" to patients with massive trauma. The study was carried out at a U. S. Army Clearing Company in Southern I Corps, in the Republic of Vietnam from January to July, 1969. The mission of the Clearing Company in combat situations is to receive casualties directly from the field by helicopter, to provide emergency resuscitative care, and then to evacuate those patients requiring immediate surgical operation. The Clearing Company has the capability of providing intravenous fluids including unmatched low titer O-positive whole blood. Emergency airways, mechanical ventilatory assistance, chest tubes and other first-aid measures were available, but the nearest definitive surgical capability was 55 miles away. Under ordinary circumstances evacuation to a surgical hospital required 45 minutes by helicopter.

The study was prompted because of the large number of mine and booby trap injuries which occurred in this part of Vietnam. Patients with this type of injury typically incur extensive trauma to the lower extremities, perineum and pelvis. These injuries had been uniformly fatal in our experience despite vigorous resuscitation including massive transfusion. Almost all patients died either en route to, or shortly after arrival at, the surgical hospital.

Materials and Methods

Patients were all males, aged 18 to 24 years. Four were members of the U. S. Army and four were Vietnamese. All had extensive trauma to the lower extremities, pelvis and perineum. None had any known injury above the diaphragm. All were considered, on the basis of past experience, to

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have an extremely poor prognosis, and the use of the "G-suit" was considered a desperate measure. Commercially available "G-suits" were utilized, and inflated to a pressure of 30 to 40 cm. water. This pressure was maintained during helicopter evacuation, by clamping the input tube. All clinical observations were made by one of us (B. S. C.) and the members of Company B, 23rd Medical Battalion. Follow-up data and operative findings were supplied by the surgeons caring for the patients at the receiving hospital.

Case Reports

Case 1. A 19-year-old South Vietnamese man arrived shortly following traumatic amputation of both lower extremities above the knees associated with penetrating wounds of the perineum. There was no obtainable pulse or blood pressure. A large intravenous catheter was placed in the subclavian vein and rapid infusion of whole blood begun. Following the fourth unit of blood cardiac arrest occurred. Endotracheal intubation was accomplished and external cardiac massage administered; bicarbonate and epinephrine were administered intravenously. Although the patient appeared unsalvageable, he was placed in the "G-suit." Within a few minutes blood pressure was 60/40 and pulse 160. The patient was bleeding briskly from the amputation stumps; therefore the "G-suit" was temporarily removed in order to apply tight pressure dressings. Upon reinflating the "G-suit" and following the eighth unit of whole blood, the blood pressure was 100/70. The patient was successfully evacuated, received definitive surgical treatment for the lower extremity trauma, and survived.

Case 2. An 18-year-old U. S. Army PFC, victim of a booby trap injury, sustained multiple fragment wounds of both legs and open fractures of the right tibia and left femur. He had no measurable pulse or blood pressure on arrival. Simultaneously endotracheal intubation and venous cut-downs were performed and the patient was placed in the "G-suit." The blood pressure became measurable at 40/0 with a very rapid pulse. Following the intravenous infusion of six units of whole blood and two liters of lactated Ringer's solution, the blood pressure was 90/76 mm. Hg. Although the patient survived evacuation, he died before definitive operation could be carried out.

Case 3. A 20-year-old U. S. Army SP/4 was impaled with multiple fragments of wood when a rocket landed on the top of his bunker. He had multiple penetrating wounds of the lower abdo-

men, pelvis and legs. On arrival he was alert but dyspneic; pulse was 160, and no blood pressure was obtainable. The patient was transfused with six units of whole blood and one liter of lactated Ringer's. The pulse remained thready at a rate of 160, and the blood pressure was still unobtainable. He gradually became more unresponsive and required endotracheal intubation. He was placed in the "G-suit" and the blood pressure dramatically rose to 120/90; his pulse dropped to 110; and the patient regained consciousness. In spite of a one hour delay in evacuation due to bad weather, the patient arrived at the surgical hospital in good condition. At laparotomy a lacerated inferior vena cava was successfully sutured. The patient subsequently survived bilateral lower extremity amputations.

Case 4. A 20-year-old South Vietnamese soldier had received multiple fragment wounds of the buttocks and perineum from a hand-grenade. No blood pressure or peripheral pulse was obtainable on admission. He was immediately placed in the "G-suit," and transfused with six units of whole blood and one liter of lactated Ringer's solution. Vital signs were still not determinable, and subsequently multiple cardiac arrests occurred which were finally unresponsive to bicarbonate, epinephrine and external cardiac massage. The patient died before he could be evacuated.

Case 5. A 24-year-old U. S. Army PFC sustained multiple mortar fragment wounds of the lower abdomen with evisceration. On arrival blood pressure was unrecordable and pulse rate was 180. Simultaneously venous cut-downs were performed in his upper extremities, endotracheal intubation was carried out, and the "G-suit" applied. Following seven units of whole blood and 2,000 cc. of Ringer's lactate solution, the blood pressure was 90/58 and the pulse had slowed to 130. The patient was successfully evacuated. At laparotomy transection of the bladder and rectum and lacerations of the left iliac artery and vein were found. There was massive hemorrhage from numerous bleeding points within the pelvis. The patient did not survive the operation.

Case 6. A 19-year-old U. S. Army PFC received multiple fragment wounds of the perineum, buttocks and legs from a land mine. On arrival blood pressure was 40/0 and the pulse 180. The patient was initially conscious, but subsequently became unresponsive and required endotracheal intubation. Four units of whole blood and 1,500 cc. of lactated Ringer's solution was administered with no improvement in vital signs. The "G-suit" was applied and the blood pressure rose abruptly to 80/60. Two more units of whole blood did not increase the blood pressure. The patient was successfully evacuated. At laparotomy he was found to have massive retroperitoneal hemorrhage from a fractured pelvis and diffuse venous oozing. The

bleeding could not be controlled and the abdomen was closed and packed. The patient died a few hours following operation.

Case 7. A 17-year-old Vietnamese man received a gunshot wound of the right upper quadrant. On admission he had no palpable pulse and no recordable blood pressure. Resuscitation consisted of endotracheal intubation, venous cut-downs, transfusion of four units of whole blood and two liters of lactated Ringer's solution and application of a "G-suit." A thready pulse became palpable, but still no blood pressure could be recorded. With continued transfusion, blood pressure reached 100/60 while the pulse remained at 140. X-rays showed a bullet in the right lobe of the liver. Following evacuation to the surgical hospital, the "G-suit" was removed and the blood pressure was again unobtainable. The "G-suit" was temporarily reinflated. At laparotomy there was extensive damage to the right lobe of the liver. The patient survived right hepatic lobectomy.

Case 8. A 24-year-old U. S. Army engineer received traumatic amputations of both lower extremities when the truck in which he was riding struck a mine. On arrival there was no obtainable blood pressure and a barely palpable pulse at 180. He was immediately placed in the "G-suit" with a decrease in pulse rate to 130. He was transfused five units of whole blood. Blood pressure was now 100/70. Bleeding resumed from the lower extremities and the "G-suit" was removed and pressure dressings applied. The blood pressure was well maintained during evacuation, and the patient survived bilateral amputations.

Comment

All patients arrived at our medical facility in profound hypotension from massive blood loss secondary to acute trauma. Our experience with such patients had been that in spite of vigorous resuscitation, including massive transfusion, they invariably succumbed en route to a surgical hospital. Following incorporation of the "G-suit" into the program, seven of eight patients were successfully evacuated, and four of eight survived.

Our experience with the "G-suit" gradually evolved over the 6 months of this study. At first large intravenous catheters were used to replace whole blood, and only later when the clinical situation appeared to deteriorate, was the "G-suit" applied (Cases 1, 2, and 7). It soon became apparent that the most effective resuscita-

tion consisted of immediate application of the "G-suit" and the simultaneous administration of whole blood through upper extremity or subclavian veins.

Experience with the "G-suit" to prevent retinal ischemia in pilots during World War II suggested to Gardner and Storer⁶ that the application of circumferential pneumatic compression to the body below the diaphragm increases arterial resistance and further causes venous blood to be translocated centrally to allow more adequate perfusion of head and heart. We observed this clinically in patients when we were able to record increased blood pressures from the upper extremities immediately following the application of the "G-suit." In most instances the increase in blood pressure was of the same order of magnitude as the compressive force applied (30 to 40 cm. water), but in some the increase in arterial pressure was substantially greater than the force applied. Ludwig and Wangenstein⁸ demonstrated that external compression is effective in controlling hemorrhage directly by decreasing transmural pressure of the lacerated vessel. Gardner and Storer⁶ also postulated that the application of "hoop stress" by the "G-suit" tended to close the opening in the vessel. Even more important to the immediate restoration of cerebral and coronary artery perfusion by the "G-suit" appears to be the central translocation of blood from the venous reservoir of that portion of the body being compressed. This latter effect was most dramatically observed in patients 1 and 8 wherein application of the "G-suit" resulted in a prompt increase of blood pressure, and presumably cardiac output, with resumption of arterial bleeding from the traumatized lower extremities. In these patients the "G-suits" had to be removed and pressure dressings applied to control hemorrhage after which the "G-suit" was reapplied until adequate blood volume had been restored. Wangenstein¹² has given experimental support to this concept by showing a marked reduction in the size of the lumen of the inferior

vena cava on angiograms when external counterpressure was applied. Case 3 demonstrated that the "G-suit" can be effective in controlling venous hemorrhage. A dramatic rise in the peripheral blood pressure was observed following the application of external counterpressure, presumably as a result of immediate translocation of blood to the right heart from the venous capacitance reservoir in the lower half of the body.

Wangensteen *et al.*¹³ recently demonstrated that prolonged inflation of the "G-suit" in hemorrhagic shock decreased survival time of experimental animals. They not only observed a substantial rise in blood pressure, cardiac output, and total peripheral resistance when the "G-suit" was inflated but also a concomitant lactic acidosis, probably as a result of impaired perfusion of the lower extremities. The results correlate with data derived from the prolonged use of pressor agents in hemorrhagic shock. Such data indicate that external counterpressure alone is not a substitute for adequate blood volume replacement in the treatment of hemorrhagic shock. Results of the present study suggest that external counterpressure can help temporarily to support the circulation and improve chances for survival while blood is replaced and the patient is being transported to a facility capable of providing definitive surgical hemostasis.

Experience with external pneumatic compression to control intra-abdominal and lower extremity bleeding in the combat zone has potential civilian applications. In smaller hospitals, with limited personnel and whole blood reserves, the "G-suit" may help resuscitate severely traumatized patients during transportation to larger medical facilities where definitive surgical care is available.

Summary

This report describes the clinical application of external pneumatic compression as a means of temporarily controlling intra-peritoneal and lower extremity hemorrhage secondary to massive trauma. The obser-

vements were made at a forward clearing company in Vietnam under surgically primitive conditions. Eight case histories are presented in which a commercially available "G-suit" was used to treat hemorrhagic shock resulting from multiple wounds of the abdomen, pelvis, and lower extremities. Four of the eight patients survived. This clinical study suggests that the "G-suit" may be helpful in providing temporary cardiovascular support while other conventional means of resuscitation are begun and while the patient is being transported to a medical facility capable of providing definitive surgical hemostasis.

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