Pneumatic antishock garment

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The pneumatic antishock garment (PASG) has become an essential part of the armamentarium of emergency medicine. The mechanism of action is controversial, but it may involve autotransfusion, increased peripheral resistance, and/or direct tamponade. The suit is primarily indicated in hypovolemic shock, but it may be useful in other situations, such as vasodilation syndrome, fractures of the lower extremities and pelvis, and some cardiopulmonary problems. Pulmonary edema may be the only absolute contraindication, but there are other relative contraindications which require inflation of only certain portions of the garment. Deflation of the PASG is a more critical procedure than inflation and should be accomplished slowly, deliberately, and in most cases under a physician's supervision. Persons who employ the garment should be aware of possible complications, such as compartment syndrome, so that they may be recognized early and treated appropriately.

One of the essential therapeutic modalities in the prehospital arena, the emergency department, and other areas of the hospital is the pneumatic antishock garment (PASG). Although the use of a pneumatic suit was initially described by Crile[1] in 1903 as a means of controlling abdominal bleeding, PASG is only now receiving its due recognition. The term "G-suit" was applied in World War II. At that time, the garment was actually an antigravity device utilized to counteract centrifugal force and prevent postural hypotension and retinal ischemia in fighter pilots.[2] During the Vietnam War, the PASG was utilized successfully to resuscitate persons with injuries to the abdomen, perineum, and lower extremities from mine explosions.[3]

Mechanism of action

The exact mechanism of action of PASG is controversial. There are three theories at present: autotransfusion, increased peripheral resistance, and a direct tamponade effect. Various reports[4-6] estimate the shunting or redirection of 750-2,000 ml. of blood to the heart, lungs, and brain from the lower extremities and the abdomen (autotransfusion). McSwain[5] cited animal studies showing that as much as 30 percent of the circulating blood volume could be relocated. However, Gaffney and coworkers,[6] after a study done on normal men 18-30 years of age, considered that the premise of the autotransfusion theory—amount of fluid required to maintain blood pressure after removal of the PASG—was incorrect. They suggested that the effects are the result of an increased peripheral resistance, which increases the systemic afterload, and subsequently an increased mean arterial pressure. Goldsmith,[7] Bivins,[8] and Niemann[9] provided additional studies which similarly conclude that autotransfusion is not the mechanism of action. Most experts now support the theory of increased peripheral vascular resistance.[10]

Little controversy, however, exists, regarding the ability of PASG to control bleeding from both arteries and veins in the area compressed within the garment.[4-6,10,11] This occurs by decreasing the wall tension of the bleeding vessel and by decreasing blood flow to the area within the garment. The actual mechanism of action may be a combination of all these components.

Gaffney and associates[12] have recently proved that passive leg raising does not have the same effect as application of the PASG.

Indications

The clearest indication for the application of PASG is hypovolemic shock.[3,4,10,13] Although head and/or chest trauma was previously considered a relative contraindication, PASG can be effective in patients with hypovolemic shock as a result of either kind of injury. PASG does not worsen the prognosis in head injury but actually causes an improved cerebral perfusion.[14] Palafox and coworkers[15] noted no significant increase in the intra-

cranial pressure when PASG were applied to animals in which hemorrhage was induced. Increased intrathoracic pressure results from the application of PASG and may slightly increase total blood loss as a result of chest trauma.[16] However, in patients with evidence of hemodynamic compensation, as may result from tension pneumothorax or ruptured aortic aneurysm, PASG will divert blood back to the thorax under sufficient pressure to increase cardiac filling and increase the central intravascular volume.[16] Thus, the use of PASG in head and chest trauma allows for maintenance of an adequate blood pressure and adequate perfusion until other definitive therapeutic maneuvers can be accomplished.

Occasionally, electromechanical dissociation (EMD) may be the only manifestation of hypovolemic shock. In such cases, the application of PASG can be a life-saving maneuver.[2]

PASG is also indicated for the treatment of vasodilation syndromes. Conditions such as drug overdose, septic and spinal shock, anaphylaxis, and envenomation are affected beneficially by application.[17]

Patients with fractures of the lower extremities and pelvis can be treated for stabilization, to control hemorrhage and prevent dangerous sequelae such as retroperitoneal hematoma.[18]

There is considerable controversy over the use of PASG in cardiopulmonary resuscitation (CPR). It is now thought that effective CPR results from increased intrathoracic pressure. Inflation of the abdominal compartment also results in increased intrathoracic pressure. In a recent study, Mahoney and Mirick[19] showed significant improvement in patients with pulseless idioventricular rhythm (PIVR) and refractory cardiopulmonary arrest. Lilja and coauthors[20] reported very beneficial effects on the systolic blood pressure of patients who had sustained cardiac arrest and undergone CPR. When Davis and coworkers[21] induced pericardial tamponade in intubated, mongrel dogs, they found that PASG improved right atrial pressure, systemic arterial pressure, and cardiac output.

Pittsburgh area paramedics utilize PASG as indicated in the prehospital setting for patients with a systolic blood pressure of 100 mm. Hg or less without pulmonary edema regardless of the etiology. Paramedics have noted that application has made starting a peripheral intravenous line significantly easier because the veins of the upper extremity become more prominent.[16] PASG can also be considered an effective, reversible fluid challenge to determine whether hypotension is indeed the result of hypovolemia.[22]

There are also indications for the application of PASG after the patient leaves the emergency department for the surgical suite. Patients who require major vascular surgery, neurosurgery, or orthopedic surgery can benefit substantially (Table 1).

Contraindications

The only absolute contraindication to the application of PASG is pulmonary edema, although theoretically since preload is not primarily affected, this may not be as "absolute" as was once considered.[23] Relative contraindications include patients with increased intracranial pressure in the absence of hemodynamic compromise and chest trauma without systemic hypotension. Thoracic trauma and other conditions with bleeding above the diaphragm and head trauma in the presence of hemodynamic compromise are *not* contraindications for reasons mentioned previously. Risk/benefit considerations are necessary in postpartum patients as a result of McBride's case report of an embolism in a woman with vaginal bleeding.[24]

The abdominal compartment should not be inflated in pregnant patients, those with an evisceration, or those with an impaled object. The extremity compartments can be inflated as usual without serious sequelae. It is also possible to inflate one of the extremity compartments in the presence of a neurovascular injury to the contralateral lower extremity. The abdominal compartment should not be inflated in these cases.

Variceal bleeding is another contraindication as increased bleeding may result.[25] Micturition, defecation, and emesis may result with inflation, the latter necessitating vigilance for aspiration.

The application of PASG in burn trauma could reduce the already compromised local circulation and thus result in further ischemia.[5]

Application of PASG certainly makes abdomi-

TABLE 1. INDICATIONS FOR APPLICATION OF PASG.

1. Hypovolemic shock
   - Head trauma
   - Chest trauma
   - Electromechanical dissociation
2. Vasodilation syndromes
   - Drug overdose
   - Septic shock
   - Spinal shock
   - Anaphylaxis
   - Envenomation
3. Fractures
   - Lower extremities
   - Pelvis
4. Cardiogenic shock (controversial)
5. Surgery

TABLE 2. POTENTIAL CONTRAINDICATIONS OF THE USE OF PASG.

1. Pulmonary edema
2. Increased intracranial pressure without hemodynamic compromise
3. Chest trauma without systemic hypotension
4. Postpartum bleeding
5. Burn patients
6. Abdominal compartment
   - Pregnancy
   - Evisceration
   - Impaled objects
   - Variceal bleeding

nal examination more difficult.[16] When possible, this part of the examination should be completed prior to application. Another disadvantage is the inability to visualize the skin color of the legs beneath the extremity compartments.[16] When field application is required, observations regarding skin color should be noted by the paramedics and reported to the attending physician (Table 2).

Technical considerations

Prior to inflation, the abdomen, pelvis, and lower extremities should be examined. Keys and other materials should be removed from pockets. Bony areas should be appropriately padded.

Inflation is accomplished with the use of the foot pump until either the blood pressure is above 100 mm. Hg, the garment trousers indent with firm pressure, or the popoff valves are released. Pressures below mean arterial pressure are sufficient to control both arterial and venous bleeding.[4] The autotransfusion theory suggests that trouser pressure of 20-30 mm. Hg mobilizes 0-6 cc./kg. of blood, while pressures of 60 mm. Hg will mobilize 10-16 cc./kg.[2] The patient's vital signs, particularly blood pressure, should always be monitored continuously. Changes in the atmospheric pressure that result from air-ambulance transport and temperature changes will result in pressure changes in PASG. The patient should be monitored and treated appropriately. Inflation may be simplified and monitoring accomplished with the use of an oxygen flowmeter, as described by Reines and Khoury.[26]

For ease of application, the PASG can be placed on the gurney before the patient if a possible indication exists. Foley catheterization, electrocardiography, arterial blood gas determination, and rectal examinations all can be accomplished with the PASG in place. The use of traction devices concomitantly with PASG, particularly in patients with peripheral vascular disease, may result in tissue ischemia,[27] in sharp contradistinction to previous suggestions.

The duration of inflation may be for several minutes to as long as 96 hours.[2] The duration of application after bleeding is controlled is controversial, with Brooks and Grenvik[18] arbitrarily utilizing 24 hours.

It must be emphasized that it is blood pressure and *not* trouser pressure that should be monitored.[5] However, the actual inflation pressure can be modified according to the indication for application. The patient with hypovolemia requires inflation until an acceptable blood pressure response is obtained. Wayne and Macdonald[28] suggest that these patients do not respond to low-pressure inflation. Patients requiring hemorrhage control need a trouser pressure of approximately 40 mm. Hg.[5] Fracture stabilization requires inflation to the point of stiffness of the garment itself.

The *critical* procedure is deflation. If surgery is indicated, deflation should be accomplished in the operating room. If deflation is to be accomplished in the emergency department or critical care unit, it should be done in a slow, deliberate fashion under a physician's supervision. Rapid deflation decreases peripheral resistance and blood pressure drops dramatically. With the use of the gauges, decremental deflation of trouser pressure by 5 mm. Hg with concomitant blood pressure monitoring will insure the best possible outcome for the patient. McSwain[16] has suggested that this procedure take 20-30 minutes.

Deflation should *never* be accomplished in the field nor should it be carried out to inspect underlying areas. Unless appropriate fluids are given during deflation, the blood pressure could drop as much as 40-60 mm. Hg.[3] It should be remembered that reinflation does not restore systolic blood pressure to the level previously achieved by PASG.

Deflation should be considered in patients whose respiratory condition significantly deteriorates after application. Deflation in this instance should be rapid.[29]

Complications

As with other beneficial therapeutic modalities, there may occasionally be complications from the application of the PASG. Persons who utilize the garment should be aware of these complications so that they may be recognized early and treated appropriately.

The most commonly discussed complication is compartment syndrome. Although usually seen in patients with lower extremity trauma,[30] this has also been described in a patient with stab wounds to the neck and no associated trauma to the lower extremity.[31] Although there are many anecdotal reports, in a large retrospective study of 821 cases,

Wayne and Macdonald report *no* cases of compartmental syndrome.[22] The etiology is controversial and may be related to either decreased transmural pressure on the arterioles within the garment or decreased capillary perfusion pressure. Compartment syndrome may also be related to the duration of inflation and/or trouser pressure, although Williams[32] reported a case after only 2 hours 10 minutes. Patients at higher risk should be considered for early angiography, early fasciotomy, vigorous concomitant fluid administration, and PASG removal as soon as hemodynamic stability has been reached. All patients require close monitoring of lower extremity perfusion.

Spinal cord complications can also result from movement of the spine after inflation of the abdominal compartment. Rockwell and coworkers[33] described a car accident victim who lost sensation and motor function in both legs upon arrival at the hospital. Subsequent x-ray examination revealed a fracture of T10. Utilizing human volunteers, Rockwell and associates[33] noted that abdominal and extremity pressure of 50 mm. Hg will elevate the lumbar spine 4-5 cm. and inflation of the abdominal compartment to 100 mm. Hg will result in an elevation of 8 cm. A subsequent modification of the garment allows for only the anterior portion of the abdominal compartment to be inflated; as a result, spinal elevation would be reduced by 68 percent.

When blood pressure is below trouser pressure for several hours, anaerobic metabolism and thus an accumulation of lactic acid may result.[34] If, however, application of the garment elevates blood pressure above trouser pressure, this does not occur clinically.[5]

Decrease in pulmonary function apparently does not result from garment application unless there is associated neurologic impairment[35]or if the garment has a large abdominal compartment.[36] Maintenance of pulmonary function may result from increased respiratory rate.[35]

Similarly, renal vascular perfusion is maintained during application of PASG.[37] Urinary output usually will remain unchanged and actually may improve[38] (Table 3).

TABLE 3. THEORETICAL COMPLICATIONS OF THE USE OF PASG.

1. Compression syndrome
2. Spinal cord complications
3. Lactic acid accumulation
4. Decreased pulmonary function
5. Decreased renal function

Summary

The pneumatic antishock garment is an essential adjunct in the resuscitation of the critically ill and injured patient. The mechanism of action is predominantly increased peripheral resistance *not* autotransfusion. There is also an associated direct tamponade effect. PASG is indicated for hypovolemic shock, vasodilation syndromes, fractures of the lower extremities and pelvis, and in certain surgical situations. There is controversy regarding PASG in cardiogenic shock, with the most recent literature being non-supportive due to increased afterload. PASG is contraindicated in patients with increased intracranial pressure *without* hemodynamic compromise, chest trauma *without* systemic hypotension, postpartum bleeding, and burn patients. Recent evidence delineating the mechanism of action may remove pulmonary edema as an absolute contraindication. The abdominal compartment should not be inflated in pregnant patients, patients with evisceration, impaled objects, and variceal bleeding. Theoretical complications have been reported citing numerous case studies of compression syndrome, spinal cord complications, lactic acid accumulation, decreased pulmonary functions, and decreased renal perfusion. Technical adjustments in the manufacture of the pants have eliminated the spinal cord complications. Wayne and Macdonald[22] studied 1,120 patients of whom 821 survived 24 hours and had an incidence of only 33 cases (4 percent) with skin ischemia (none with compartment syndrome) and 8 cases (0.97 percent) of renal failure requiring dialysis.

Thus, the appropriate use of the pneumatic antishock garment will increase perfusion to the heart, lungs, and brain. The patient may not only have an improved chance of survival but an improved quality of life after survival.

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