CARDIOVASCULAR DYSFUNCTION IN BURNS: REVIEW OF THE LITERATURE

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SUMMARY. Major burn injury produces substantial hemodynamic and cardiodynamic derangements, which contribute to the development of sepsis, multiple organ failure, and death. Cardiac stress is the hallmark of the acute phase response and its severity determines postburn outcomes, with poorer outcomes associated with cardiac dysfunction. With available evidence from the literature, the present is a comprehensive review of cardiac dysfunction in burns as well as the different monitoring modalities.

Keywords: Burn, Cardiac dysfunction, treatment

Introduction

Major burn injury produces substantial hemodynamic and cardiodynamic derangements, which contribute to the development of sepsis, multiple organ failure, and death. Cardiac stress is the hallmark of the acute phase response and poorer outcomes of burn injury have been associated with severe cardiac dysfunction[1,2,3]. Compromised cardiac function results in organ hypoperfusion, impaired peripheral microcirculation, burn zone extension, and reduced resistance to bacterial infection at the wound site[2].

Physiologically, myocardial dysfunction following thermal injury is characterized by slowed isovolemic relaxation, impaired contractility, and decreased diastolic compliance of the left ventricle[4,5]. This is manifested primarily by a decrease in cardiac output and metabolic rate with compensatory increments in heart rate and peripheral vascular resistance[6,7,8] which increase myocardial oxygen demand, leading ultimately to right and left heart deficits[4,10]. Depending on the extent of the burn, this deficit might result in a state of cardiogenic shock[11], which has been identified as a major cause of failed resuscitation[12].

In addition to the increased mortality associated to cardiac dysfunction during the acute hospitalization[13,14], a prolonged derangement can lead to an increase in long-term morbidity. In fact, burn-related dysfunction that was believed to be transient, with maximal dysfunction apparent 18 – 30 hours postburn followed by recovery of cardiac function 48 – 60 hrs postburn[15,16,17], has now been proven to last for up to 2 years in burned children[1]

The present is a comprehensive review of cardiac dysfunction in burns using available evidence from the literature. A Medline, Scopus and Pubmed database search was conducted to identify citations related to cardiac dysfunction in burns, in human as well as in animal models, published between 1930 and 2011.Key words used for the search comprised “Burn”, “Cardiac dysfunction”, and “treatment”. Meshword search included “Burns”, “Therapeutics”, “Heart”, “ventricular dysfunction”, “heart failure” and “heart diseases”. Study references were also screened manually in order to identify potential citations not captured by the initial database search. Level of evidence of each article was not investigated. Inclusion criteria included English-language articles dealing with humans as well as animal models, case reports, review and original articles. Exclusion criteria included reports of only successful cases, articles with unclear explanations, results and guidelines.

Cardiovascular changes following burns

Following burn injury, there is a substantial loss in circulating plasma fluid volume due to increased capillary permeability[18] accompanied by a decreased cardiac output and compensatory increments in heart rate and peripheral

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vascular resistance[19,20,21,7,22,23]. Increased pulmonary resistance and therefore increased right ventricular work-load is an additional factor in cardiac dysfunction[12]. These changes are proportionally dependent upon the size and extent of the thermal burn[24]. Patients with larger burns are more likely to develop biventricular failure[12]. Ultimately, the cardiac deficit culminates in a state of shock [23,25,26,27,28,29].

Hemodynamic features of burn shock comprise a decrease in:

1. Cardiac output (in the order of 40-60%)[6,7,8]
2. Stroke volume[7,30]
3. Venous return[25,31]
4. Coronary blood flow[29,30,32]
5. Peak systolic blood pressure[30]
6. Mean arterial pressure[8,23]
7. Estimated myocardial work[30]
8. Stroke work[30]
9. Myocardial oxygen consumption[29,30,33]
10. Myocardial metabolic activity[25,31]
11. Myocardial oxygenation (ischemia)[34]
12. Myocardial contractility[30,35,36,37]
13. Myocardial compliance[30,38]

Following major burn injuries lower cardiac output and higher mean arterial pressure have been observed in non-survivors. Perfusion of many body tissues is thus much more impaired in non-survivors compared to survivors, as evidenced by a higher lactic acid level.

Extra-cardiac factors

Immediately following thermal injury, plasma losses may be in excess of 4mL per kilogram of body weight per hour in a burn exceeding 30% of the total body surface area (TBSA)[39]. In 1931, Blalock suggested that depressed cardiovascular function in burn shock was primarily a sequel of vascular fluid loss[40].

Others have demonstrated changes in endocrine and sympathetic nervous system activities. Following severe burns, there are elevated plasma levels of catecholamines, vasopressin, angiotensin-II[41,42,43,44] and neuropeptide-Y which, despite adequate resuscitation as assessed by normal central venous pressure, pulmonary capillary wedge pressure and mean arterial pressure, may have deleterious effects on cardiovascular function[7,45,46,47].

Levels of vasopressin, a potent natural constrictor of blood vessels, increase four-to-six fold within ten minutes after the burn[48,49,50] and return to normal by the 5th day[7]. Vasopressin plays a role in the initial decrease in myocardial force of contraction. This may be partly because of coronary constriction [45].

Elevated catecholamines are important in supporting cardiac output following burns. That is why β-adrenergic blocking agents may reduce cardiac function when used following thermal injury[51]. Burn injury, however, alters β-adrenergic receptor function[52]. Pharmacologic blockade of the sympathetic system during the immediate postburn period paradoxically results in marked improvement in cardiac function[53].

Intrinsic cardiac factors

The decline in cardiac output following burns does not parallel loss in plasma volume[23,54,55]. As early as 1957 Gilmore reported that restoring plasma volume 1 hour after the burn had only a minimal effect on increasing cardiac output[56]. Others have shown that fluid resuscitation that is adequate to replace intravascular volume does not always restore stroke volume or cardiac function[30,57,58].

Cardiac depression can be detected as early as 15 minutes post burn. Since hematocrit is only moderately elevated (if at all) at that time, one of the components of cardiac depression at least in the early stages is not related to hypovolemia[23]. In addition cardiac output and stroke volume diminish without significant changes in central venous pressure and pulmonary capillary wedge pressure[7,34].

There is mounting evidence of early direct damage to myocardial cells[21]. Considerable amount of myocardial proteins and degradation products are detected after severe burns[59]. Experimentally, it has been demonstrated that the heart of burned dogs release the intracellular enzyme, lactate dehydrogenase[60]. Cardiac biochemical markers reflecting cardiac myocyte damage, including troponin T, cardiac myosin light chain 1, cardiac-specific isoenzyme compound, are all significantly elevated between 1 and 24 hours following the burn[61,62].

Burn mediated alterations in calcium homeostasis contribute as well to the development of cardiac dysfunction[63]. Levels of cytoplasmic Ca^{2+} in cardiomyocytes are increased at 1 hour post-burn, followed by enhanced mitochondrial Ca^{2+} at 3 hours. Sarcoplasmic reticulum transport function depression is implicated in the increase in intracellular Ca^{2+} levels[64,65]. Decreased myocardial contraction, relaxation capacity and increased ventricular wall stiffness parallel the changes in Ca^{2+} levels in the burned rat. This might explain the rigor contraction and decreased relaxation of myocardium observed following burn injury[66]. Limiting intracellular cardiac Ca^{2+} accumulation after burn trauma, using a calcium antagonist, was found to improve cardiac function[26,67].

Experimentally, maximal rate of cardiac fibers relaxation is uniformly less in burned compared to unburned animals. Contraction properties of isolated myocytes are also depressed and maximal rate of relaxation in response to increased stimulation frequency and to increased calcium ion concentration is reduced as well[68,69]. Papillary muscles from burnt rabbits are mechanically dysfunctional and the ionotropic deficit is accentuated by high stimulation frequency.

Destruction of cardiac myocytes might be an important factor causing a decrease of cardiac contractility[70]. 24 hours following the burn injury, there is a marked increase in apoptotic cells in the left ventricle and the number of apoptotic cells remain increased by eightfold 48 hours post burn. Apoptosis occurs predominantly in the subendocardial tissue of the left ventricle. The appearance of apoptotic cells is coupled to a decrease in cardiac mechanical function with significant decrease in left ventricular pressure and rate of ventricular pressure change[71]. Although apoptosis of myocytes occurs within 24 hours of a major burn injury contemporaneously with myocardial dysfunction, it is not known whether the apoptosis is the cause of cardiac dysfunction or secondary to it.

Role of cytokines

The inflammatory sequel to burn including cytokine release, activation of the complement cascade, neutrophil adherence and activation, release of free radicals and an increase in intracellular calcium[72,73,74,75] may serve to incite and propagate cardiac dysfunction.

Circulatory cardiotoxic substances have always been assumed to be operative in burn shock[25,76,77,78]. There is increasing evidence that inflammatory mediators or cytokines that propagate and regulate post burn inflammation are these cardiotoxic substances. Local inflammatory mediators have been also associated to advanced heart failure resulting from diverse pathological conditions[79]. Cytokines directly implicated in mediating myocardial depression in systemic sepsis and other forms of systemic inflammation include TNF-α, IL-1β, IL-2, IL-6 and IFN-gamma[79,80,81].

TNF-α (tumor necrosis factor) is a multifunctional cytokine detected in several human cardiac related conditions, including congestive cardiac failure and septic cardiomyopathy, and has been implicated as well in cardiac dysfunction following burns[16,82]. There is in addition a close relationship between TNF-α and multiple organ dysfunction following burns[83,84]. TNF-α was shown to depress cardiac contractility, intracellular calcium currents and induce programmed cell death (apoptosis) of cardiomyocytes in experiments simulating ischemic conditions of the heart[85]. Apoptosis resulting in rapid and reversible declines in contractile function is directly proportional to TNF-α levels [86,87]. High concentrations of TNF-α (>1000 U/mL), have been shown to promote cardiac apoptosis, resulting in rapid and reversible declines in contractile function in isolated hamster papillary muscles, adult guinea pig and rabbit ventricular myocytes[86,87]. Cardiovascular abnormalities have been detected in canines receiving different intravenous doses of human recombinant TNF-α. The mean left ventricular ejection fraction 2 hours after TNF-α injection decreased compared to the control. The group receiving the highest dose of TNF-α had the greatest decrease in mean left ventricular ejection fraction coupled to a significant decrease in cardiac contractility[88].

Partly released by cardiac cells following burn injury, TNF-α can be found in serum following major burns[89,90,91,92,93]. During the post-burn inflammatory reaction, myocardial levels of TNF-α might be, however, higher than that in serum. It is possible that both systemic and local production of TNF-α after burn trauma contribute to myocyte apoptosis and subsequent cardiac dysfunction. In support of this possibility, therapy with monoclonal antibodies to CD54 has been found to inhibit both cardiac dysfunction as well as the increase in serum TNF-α after burn injury and septic shock[89,90,94,95,96,97,98,99].

Some authors demonstrated a gradual decline in cardiac contractile function in dogs injected with recombinant TNF-α and IL-1β[100], yet others[101] identified a biphasic effect in conscious chronically instrumented dog model. In this preparation, recombinant human TNF-α increased left ventricular contractile function within minutes, followed by a gradual profound decline in ventricular systolic function that took several hours to manifest.

Following exposure to inflammatory cytokines, cellular components within the heart including microvascular and endocardial endothelium, vascular smooth muscle and cardiac myocyte express cytokine-inducible "high output" isoform of nitric acid synthase[102]. A marked increase in cytokine-inducible nitric oxide synthase (iNOS) activity peaking at 8 hours has been reported post-burns. A significant increase in myocardial nitric oxide and cyclic guanosine monophosphate (Cyclic GMP) production parallels iNOS increase[103]. Pinsky *et al.* documented that iNOS induction by TNF-α and IL-1β in adult rat ventricular myocytes promoted myocyte death[104]. The Increased iNOS expression in cardiac myocytes and in microvascular and endocardial endothelial cells accounts for most of the Nitric oxide production after regional or global iNOS production in the heart; This markedly suppresses basal and β-adrenergic agonist-stimulated myocardial ionotropic responsiveness. The decline in myocardial contractile function after the iNOS induction by cytokines is likely to be due to NO-dependant activation of guanylyl cyclase, increased intracellular cGMP as well as non cGMP dependant effects of NO[104,105,106,107]. Subsequent reports have implicated induction of a NO-dependent pathway in these cells by cytokines[108].

Induction of iNOS by cytokines in cardiac myocytes is enhanced and sustained by rise in intracellular cAMP and activation of diacylglycerol-regulated protein kinase C after exposure to catecholamines or peptide autocoids such as angiotensin II and arginine vasopressin[109,110,111,112,113]. This could explain their role in cardiac dysfunction following burns and the improvement in cardiac function seen following their inhibition.

The physiological effects of NO are mediated through guanylate cyclase[114] which is present within the heart in

several cell types, including ventricular myocytes[115]. NO is synthesized from L-arginine by nitric oxide synthase. NO oxide released from endocardial cells contributes to modulation of myocardial contractility[116,117] by increasing the level of cyclic GMP in cardiac muscle and thus exerting a negative ionotropic effect[118]. The mechanism of action is likely due to the cyclic-GMP-mediated inhibition of the entry of Ca^{2+} into the cell by activation of cyclic-GMP dependent protein kinase[119]. This could explain earlier findings by Hilton and Marullo, in 1986, showing improved cardiac output by using calcium channel blockers following thermal injury[120].

Smoke inhalation and myocardial function

Concomitant smoke inhalation can cause right ventricular dysfunction due to pulmonary artery increased resistance and hypertension with resultant increase in right ventricular workload[121]. This is seen as a significant increase in end-diastolic volumes, decrease in ejection fractions and low stroke work indices. Left ventricular dysfunction can be either explained by global myocardial insufficiency or by a left-sided shift of the interventricular septum caused by overfilling of the right ventricle[122,123]. Moreover, smoke inhalation dictates an increase in fluid infusion regimen[124,125,126], complicated by the fact that capillary refill and arterial filling pressures may be misleading in patients with pulmonary injuries[127,128,129,130].

Carbon monoxide (CO) poisoning, by creating a more hypoxic intracellular environment, further complicates myocardial damage from smoke inhalation[131]. It manifests as ECG changes, dysrhythmias, congestive heart failure or hypotension[132]. CO combines with hemoglobin with an affinity 200 to 250 times greater than that of oxygen decreasing its oxygen carrying capacity. It disrupts as well intracellular utilization of oxygen by binding to cytochrome-a3 and to myoglobin[133]. This amplifies cardiac workload and thus oxygen requirements of an already ischemic heart, increasing the risk of myocardial infarction[134]. Moreover, CO increases platelet adherence and with it the risk of thrombotic events[135]. Animal studies demonstrated that CO decreases the threshold needed to induce ventricular fibrillation and increases the extent of myocardial injury that accompanies infarction[136,137], but has no direct vasoconstrictive effects[138]. Animal and human studies demonstrated the histology of CO-induced myocardial injury. It consists of focal areas of hemorrhage and necrosis, frequently involving the subendocardium and papillary muscle[139].

Gender differences in relation to myocardial function following in burns and sepsis

Gender has been shown to be an important determinant of outcome in patients with traumatic injury and sepsis[140]. Although age and the female gender have been associated with a worse prognosis in acute myocardial infarction[141], other studies have described a better survival rate for women with sepsis[142,143,144,145,146]. The mechanisms of gender-related differences in outcome following injury and disease remain unclear, but sexual dimorphism in pro- and anti-inflammatory responses to injury have been implicated. In this regard, Schroeder and colleagues[145] suggested that the significantly improved prognoses for women with sepsis compared with men correlated with significantly lower TNF-α bioactivity and increased levels of IL-10. Similarly, Oberholzer and colleagues[143] described higher plasma IL-6 levels in severely injured males compared with levels measured in females with a similar injury severity score during the early post-trauma period. Balteskard and colleagues[147] described lower thromboxane B_2 and TNF-α levels in young women compared with young male trauma patients, however, differences in inflammatory cytokine profiles decrease with increasing age, particularly with the onset of menopause.

Gender-related differences in myocardial inflammatory responses after burn injury were examined by Horton *et al*[140] in burned male and female (either diestrus or proestrus/estrus) rats. It was found that burn trauma increased cardiomyocyte secretion of TNF-α, IL-1β, and NO to a lesser extent in proestrus/estrus females than levels secreted by either diestrus females or males. Similarly, myocytes from proestrus/estrus females accumulated significantly less sodium/calcium compared with values measured in males. The finding that proestrus/estrus females had less myocardial contractile dysfunction compared with diestrus females is consistent with previous reports showing that hormonal status plays a significant role in injury and disease[148,149,150,151,152,153]. That estrogen modulates numerous injury- and disease-related responses has been supported by the finding that administration of low levels of estrogen in males improved peripheral vasoconstrictor responses to catecholamines[154,155] and improved immune function and outcome in models of trauma-hemorrhage or polymicrobial sepsis. Similarly, administration of testosterone receptor blockade or castration have been associated with improved organ blood flow, improved tissue oxygen consumption, and improved cardiac and hepatic function in males subjected to trauma-hemorrhage[143].

Burn injury and the elderly

It has long been established that cardiovascular regulation progressively deteriorated with aging. Previous studies have demonstrated age-related alterations in cardiac receptor response to changes in blood volume[156], increase in mycocyte size and alterations in myocardial collagen leading to progressively left ventricular hypertrophy[157]. Older hearts have been shown to have lower levels of endoge-

nous norepinephrine, a decreased ability to retain norepinephrine in storage granules[158] with diminished responsiveness to beta-adrenergic stimulation[159]. Age related changes in cardiac contraction and relaxation have also been attributed to deterioration of calcium pump function of the cardiac sarcoplasmic reticulum[160,161,162]. It is therefore reasonable that cardiac dysfunction following thermal injury is more pronounced and does not respond to fluid resuscitation in the elderly[26,163,164]. In addition, there seem to be a correlation between older age groups and the likelihood to develop right ventricular dysfunction following thermal injury[12]. A higher mortality and failure of resuscitation rates in the elderly burn subject is probably related to these changes.

Burns and children

It is now recognized that burn injury in children is a special problem, which has significant pathophysiological differences from that in adults[173,165,166,168,169,170]. In one cohort, it was shown that children with burns equal to or over 60% of TBSA develop depressed left ventricular function, of which 38% had concomitant right ventricular failure[171]. Moreover The infant's heart seems to be more vulnerable to the effects of oxygen radicals[174], and has significantly lower concentrations of free radical scavenging enzymes compared to adults[175]. Several studies have shown developmental differences in cardiac sarcoplasmic reticulum function, including an age related decrease in calcium transport capacity in sarcoplasmic reticulum vesicles isolated from newborn hearts[176,177]. The neurohormonal response to burns in children also differs from that that of adults with similar sized burns. Vasopressin is higher on admission but returns to normal earlier than adults[7,178,179,180]. The peak in Angiotensin II is reached faster than in adults[7,178,180]. Children also have higher levels of adrenaline and lower levels of noreadrenaline than aduts[7,178].

Monitoring modalities of cardiac dysfunction in burns

Although the pathophysiology of cardiac dysfunction in burns is increasingly discerned, evidence guiding the treatment remains poor and the available methodology is still crude. It will be some time before treatment options become sufficiently refined and based on solid evidence. Standard vital signs used as measurements of circulatory adequacy are too insensitive to ensure appropriate fluid replacement, particularly in larger burns[126].

Burn resuscitation as currently practiced with existing formulas produces inadequate circulatory responses. Fluid resuscitation of patients with thermal trauma continues to be guided mostly by the urinary output and the mean arterial blood pressure. Although the goal of fluid resuscitation is the maintenance of adequate cellular perfusion, it has become clear that during resuscitation, parameters such as urine output and mean arterial pressure may not accurately reflect perfusion of organs at the cellular level. A state of poor perfusion can exist despite acceptable urinary output and blood pressure chartings[126,181,182,183].

Despite overwhelming evidence that base deficit (BD) and serum lactate are excellent markers of insufficient cellular perfusion[184,185,186], fluid resuscitation after burn injuries is rarely guided by these indices. Kaups *et al*[187] found that a base deficit of less than -6 mmol/L on admission was associated with larger burn size, profound underestimation of fluid requirements and higher mortality rates. Jeng *et al*[181] showed that indicators of poor perfusion remain elevated despite seemingly adequate fluid resuscitation based on urine output and mean arterial pressure.

The amount of lactate produced is strongly correlated with the severity of poor perfusion and the extent of accumulating oxygen debt[184,185]. Base deficit may be a better marker of poor perfusion than serum lactate because the BD represents the combined sum of lactate and all other metabolic acids released during tissue hypoxia[1875,188]. It was proven that early elevation of BD is associated with more extensive burns, inhalation injuries and a higher probability of death[189]. Furthermore, BD as well as serum lactate often remains abnormally high during fluid resuscitation even when traditional resuscitation variables, such as mean arterial pressure and urine output are maintained within acceptable limits[181]. This suggests that a state of global hypoperfusion may exist during the post-burn resuscitation despite what could be considered "adequate" resuscitation[127,183].

It was demonstrated that Predicted resuscitation volume using the Parkland Formula in patients with a BD of less than -6mmol/L is an underestimate[190]. It was hence suggested that persistent elevation of base deficit to more than -6mmol/L, even with adequate urine output can be used to identify patients who may be in a malperfusion state and who will require more resuscitation fluid than predicted. However, patients resuscitated using a goal-directed approach towards lactate levels, base excess, central venous oxygen saturation and other indicators of tissue perfusion despite adequate urine output and vital signs often receive fluid infusions more than actually needed increasing concerns about "fluid creep" and its serious complications[166]. Overresuscitation can be a major source of morbidity for burn patients. It predisposes to peripheral compartment syndromes, abdominal compartment syndrome, and pulmonary edema. Splanchnic oedema leads to an increase in gut permeability, bacterial translocation, and increased intra-abdominal pressure. It is obvious now that a "permissive hypovolaemia" approach to resuscitation after severe burns may be highly desirable[191]. It has been associated with significantly lower multiple-organ

dysfunction scores than the resuscitation with Parkland formula. Closed-loop computer-controlled resuscitation system to titrate fluid therapy to a target urine output may help avoid over-resuscitation.

The routine use of pulmonary artery catheters in patients with life-threatening burns to produce a hyperdynamic circulation similar to that recommended by Shoemaker *et al* in 1991 improves survival[192]. Earlier increase in perfused fluids with more effective resuscitation is a contributing factor to improved survival[193]. Barton *et al*[194] suggested that oxygen delivery and consumption could be improved with the combined use of volume loading and ionotropic support during the resuscitation of patient with life threatening burn injuries. However it was not determined whether this strategy reduced organ dysfunction or mortality rates. Schiller *et al*[195] compared the resuscitation of patients with severe burn injuries with the use of invasive hemodynamic monitoring and a hyperdynamic resuscitation protocol with a control group for which resuscitation was guided by traditional end points such as blood pressure, heart rate and urine output. Patients treated with hyperdynamic resuscitation have improved microcirculatory flow, tissue perfusion and tissue oxygenation and appear to have less hepatic and renal dysfunction with a significant reduction in mortality rate. There is a statistically significant difference of early hemodynamic response in those who survived compared with those who did not survive severe thermal injury. Survivors had a significantly higher cardiac index, oxygen delivery and systolic blood pressure than non-survivors[196]. The information generated by using a Swan Ganz catheter stimulates more rapid and timely decisions. This monitoring device allows for additional fluid volume administration to enhance circulatory function with resulting production of maximal hemodynamic values.

However, whether invasive monitoring improves outcome or merely defines the problem has not been proven conclusively. The use of invasive monitoring carries its own risks, especially in immunocompromised patients such as burned patients. The latter have a high risk of developing bacterial endocarditis following the use of pulmonary artery catheters[197,198], carrying a mortality rate of 95% as reported in some studies[199].

A relatively newly developed method utilizes the shape or the arterial waveform to predict cardiac output and is termed "pulse contour analysis[166]. Esophageal Doppler monitoring provides a relatively non-invasive, low cost alternative to continuous monitoring of hemodynamic indices. The Doppler probe measures mean velocity (Vm), and calculates cardiac output by adopting a modification of the flow equation. Assessment of preload, afterload and contractility can be accomplished on the basis of waveform analysis. Information from this less invasive method might be useful in guiding resuscitation by monitoring cardiac output, intrathoracic blood volume, global end-diastolic volume, extravascular lung water, pulmonary vascular permeability index, cardiac function index, global ejection fraction, pulse pressure variation, and stroke volume variation, corrected flow time (FTc) and peak velocity correlate with preload and contractility respectively [166,200]. FTc is a better indicator of preload than pulmonary capillary wedge pressures, and esophageal Doppler seems to be as useful as pulmonary artery catheters in managing the hemodynamic status of the critically ill[201]. They have been found to improve outcome and shorten hospital stay. Recent studies have looked at the role of esophageal Doppler in children with thermal injuries and have suggested their use during resuscitation[202].

Resuscitation based on oxygen transport criteria remains potentially harmful. There are risks and complications associated with the insertion of pulmonary artery catheters, with the use of ionotropes and aggressive volume loading. It would therefore be useful to have some criteria for the selection of patients who should be more aggressively monitored and resuscitated. Early elevation of base deficit may be a marker that could be used to identify those patients who might benefit most from a resuscitation strategy aimed at maximizing tissue perfusion and oxygen delivery through invasive monitoring and a hyperdynamic monitoring protocol. Elderly burn patients should be resuscitated at lower end points than younger individuals because of volume intolerance. This confirms the observation made by Monafo *et al*[203] in 1984, that non-survivors receive more fluids than survivors. Earlier increased fluids and more effective resuscitation were contributing factors to improved survival. These experiences indicate that burn resuscitation as currently practiced with existing formulas produces inadequate circulatory responses, and both survival and organ function can be improved by maximizing end points.

Conclusion

In summary, cardiac dysfunction post-burn is mediated by several factors that include plasma volume loss, smoke inhalation and hypoxia, release of hormones, and the complex interplay of inflammatory cytokines. These effects are more pronounced in extremes of age due to restricted physiological reserves .The consequences of such effects are long term dictating a close follow up on patients over a period of at least 2 years. It is obvious that adequate fluid resuscitation alone does not correct the complex cardiovascular deficits following major bur injuries. We believe that a comprehensive understanding of the physiology of cardiac dysfunction post-burn by all members of the multi-disciplinary team taking care of such complex patients cannot but further contribute to improving their outcome.

RÉSUMÉ. Les grandes brûlures provoquent des bouleversements substantiels hémodynamiques et cardiodynamiques qui contribuent au développement de la septicémie, de la défaillance multiviscérale et de la mort. Le stress cardiaque est la marque caractéristique de la réaction du corps en phase aiguë et sa gravité constitue le facteur le plus important pour ce qui concerne le résultat final : les résultats finaux les moins bons sont associés à une dysfonction cardiaque. Les Auteurs présentent une analyse exhaustive de la dysfonction cardiaque chez les patients brûlés et des diverses modalités de les monitoriser.

Mots-clés: brûlure, dysfonction cardiaque, traitement

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This paper was accepted on 27 February 2012.