Mr President, members of the Society and guests, it is a great honour and privilege for me to deliver the 23rd D. J. du Plessis Lecture in honour of a man described by his peers as ‘master surgeon, teacher and leader’. A man with vision, tenacity, integrity and compassion, one who has left an indelible and profound surgical and academic legacy, a true son of Africa.

Daniel Jacob du Plessis, or Sonny as so many of us came to know him, was born in Paarl in 1918. He was schooled at Paarl Boys’ High and completed his medical studies at the University of Cape Town (UCT) in 1941. He joined the South African armed forces and rose to the position of Captain of the 20th South African Field Ambulance in the Western Desert and Italy. He started his illustrious surgical career at the University of the Witwatersrand (Wits) and subsequently at UCT. He was one of the famous ‘seven dwarfs – giants’ who trained under Professor Charles F. M. Saint. All seven had a profound and lasting influence on the practice of surgery in South Africa. They were professors D. J. du Plessis (Wits), C. H. Derksen (University of Pretoria (UP)), J. H. Louw (UCT), F. D. du Toit van Zyl (University of Stellenbosch (US)), J. J. W. van Zyl (US), K. Bremer (UP) and M. Cole Rous (UCT). His future leadership potential was recognised early in his life. In 1951 he was elected as Nuffield Fellow to Oxford, and at the young age of 40 years was appointed Professor and Head of the Department of Surgery at Wits. The Department under his leadership became world renowned.

He was a hard taskmaster, expecting unswerving dedication from his staff, but always led from the front. He was a gifted teacher and administrator and established research, both clinical and experimental, on sound scientific foundations in...
Johannesburg and the rest of South Africa. This resulted in an ethos of enquiry and scientific endeavour in the fields of gastroenterology, endocrinology, malignancy, peripheral vascular disease, immunology and organ transplantation. He had the great foresight to establish full chairs in 9 surgical disciplines, many pioneering the field in South Africa. D. J. du Plessis also played a pivotal role in establishing the biennial surgical conference of the Association of Surgeons of South Africa, the South African Journal of Surgery, and was a founder member and patron of the Surgical Research Society of Southern Africa – a master at work.

In 1974 he became Deputy Vice-Chancellor of Wits and was invited to become Vice-Chancellor and Principal in 1978, a position he held with great esteem and success. He died on 12 September 1999. A Festschrift in his name was published by the South African Journal of Surgery in 2002.7

My association with Professor Du Plessis was occasional and took place under severely stressful circumstances, he as examiner and I as student, and also when he came as visiting Professor to the university where I studied. His imposing stature and the aura of excellence captivated our young minds and he became a surgical icon to us during our formative years. He sowed the seeds and watered the fields for scientific research, not only for me but for many others who had the privilege of working in his shadow. The regular Saturday morning surgical clinical meetings at Johannesburg Hospital formed a platform for excellent teaching. Registrars-in-training made great efforts to attend these meetings. We travelled long distances and returned inspired by what we had learned. Indeed he ignited a burning fire in us to become like him.

The first surgical research lecture (1982) bearing his name was titled ‘The Stream of Time in Surgical Research in Southern Africa’ and emphasised the following: identify what needs to be done, formulate a plan of action, and then proceed with confidence and determination. Objectives should be kept clearly in mind, be critical of all knowledge and free from preconceived ideas. He also emphasised the basic disciplines of research – accurate observation, meticulous gathering of information, deductive reasoning and objective reporting of conclusions.

I have chosen as my topic for the 23rd D. J. du Plessis lecture ‘Burns Research and Clinical Practice’ for two reasons – it embodies part of my professional career as a paediatric surgeon, and the management of thermal injuries in South Africa remains problematic, especially for the underprivileged patient.

Research in South Africa is hampered by the absence of a National Health Research programme and priorities to provide guidelines. Fiscal restraints, a more than 10-fold loss of scientific personnel in 40 years, deteriorating academic infrastructure, shortage of capacity and dependence of research on external experts, further compounds the ‘negative environment’ that researchers are working in. Ideally, research in South Africa should be into areas of prime importance and relevance and results should be translated into policy and practice – an excellent concept, but difficult to implement. The work should be relevant and of benefit to the country and its entire people.8

In 1983 when Mike Davies left for Johannesburg, I was given the task to care for burnt children at Red Cross Children’s Hospital. Although the hospital had a functional and excellent burns unit at that time, burn care in those days generally suffered from years of official neglect and professional disinterest in South Africa. There were only a handful of so-called ‘burn centres’ operating in the country. Burnt patients were mostly from the disenfranchised part of society and were often left in dark corners of hospitals and treated by inexperienced interns and doctors – a situation not dissimilar to that in many parts of South Africa today. My interest in burns was stimulated when I was attached for 9 months to the burns unit of H. F. Verwoerd Hospital under the auspices of Dr J. Jacobs, a kind and gentle man who cared for burns patients in the most admirable way.

Forty years ago the emphasis was on acute care, antibacterial therapy, biological dressings and delayed surgery. We did what we could in those days with our understanding of the pathophysiology of burns and the means at our disposal. The outcome was dismal. A 20% total body surface area (TBSA) burn was lethal, children were grouped together, at times 3 in a bed, and treated with tub hydrotherapy, topical mercurochrome and open dressing techniques. Silver sulfadiazine was not yet developed and early tangential excision and immediate grafting came only in the early 1970s. Antibiotics were seldom used. Nutrition consisted of ‘pap and milk’ and there was no pain control. At times surgery was delayed for weeks while awaiting spontaneous eschar separation, and surgical techniques were primitive. There were no programmes for rehabilitation. Now, 40 years later, survival has increased dramatically to such an extent that half of all children with a 70% TBSA burn will survive.

Value of research in burn care

Improvements in burn care have come about mainly as a result of analyses of patient data which led to the development of formulas for fluid resuscitation and nutritional support. Clinical research has demonstrated the efficacy of topical antimicrobials in delaying onset of sepsis, thereby contributing to decreased mortality of burn patients. The value of early surgical therapy in improving survival for many burned patients, by decreasing blood loss and by diminishing the occurrence of sepsis, has been substantiated through randomised trials. Basic science and clinical research have contributed to decreased mortality by elucidating the pathophysiology related to inhalation injury and by suggested treatment methods which have decreased the incidence of baro-trauma and pneumonia. Investigations of the hypermetabolic response to major burn injury led to improved management of this life-threatening phenomenon, new feeding techniques, and improved quality of life. Finally, laboratory and clinical research are addressing the vexing problems of a permanent and universal skin alternative and scar reduction.

Prevalence of thermal injuries

The management of thermal injuries in South Africa has always been problematic. There are only a few burn centres, staff shortages are critical, burn care is very costly, and morbidity and mortality numbers remain high, especially in those < 4 and > 65 years of age. It is estimated that burns affect approximately 3% of South Africans annually, with the majority of these patients treated by nurses and general practitioners. Burns are also the third commonest external cause of fatal injuries up to the age of 18 years and the main cause under the age of 4 years.9 The developing world is therefore carrying an extraordinary burden of this devastating and mostly preventable injury.10,11 Why is there such a
high incidence of thermal injury in South Africa? The answer is multifactorial and mostly owing to lack of an enabling environment, i.e. low socio-economic status, lack of infrastructure and education, traditional beliefs, and devastating diseases, i.e. malaria, epilepsy, tuberculosis, HIV/AIDS and malnutrition.

Pathophysiology

In the mid-1950s Jackman showed that following a thermal injury and depending on the temperature and duration of contact, a burn potentially consists of 3 zones of tissue destruction or damage, i.e. an area of full-thickness necrosis which is irreversible, encircled by a zone of stasis and an outer zone of hyperaemia. The zone of stasis can potentially survive, but local inflammatory inhibitors can easily lead to further vascular stasis and tissue loss. This inflammatory response can be modulated by anti-inflammatory drugs, polymyxin B, antitoxin antibiotics and antioxidants. Much of this is still in the experimental phase. The systemic response is profound and affects all systems in the body, with either upgrading or suppression of their function, leading to changes in cardiovascular, respiratory, renal, hepatic and immunological functions.

Predictors of survival

There are two main predictors of survival, viz. burn size and burn depth. Burn depth determines local and ultimately surgical management, while burn size determines fluid and metabolic needs. These factors also determine whether the patient needs the care of a specialised burns unit, as well as outcome and rehabilitation.

In practical terms, burn survival can be predicted. The Burns Index is a simple rule of thumb that adds the age of the patient to the percentage of TBSA burnt. It can now be expected that a patient with < 20% TBSA burns will have 100% survival. Even with modern treatment modalities a burn victim has a less than 50% chance of survival if the sum of age and TBSA exceeds 95. This formula applies to patients older than 20 years. The current LD50 (lethal dose) for paediatric burns at Red Cross Hospital is 70% TBSA.

Burn depth is a determining factor in deciding local and surgical management strategies. Four levels of burn injuries based on clinical assessment are generally recognised, i.e. superficial epidermal or first-degree burns, superficial partial-thickness or second-degree burns, deep partial-thickness second-degree burns, and full-thickness or subdermal third-degree burns. While the superficial burns usually heal spontaneously within 3 weeks, the deeper burns require surgical excision and grafting.

Burn depth is ascertained by the clinical appearance of the wound, colour, blanching capillary return, vessel staining, blister formation, touch and pinprick sensation. Clinical assessment is more accurate for very shallow and very deep burns. The indeterminate-depth burn remains problematic because it is only estimates to initiate fluid replacement and that survival depends greatly on prompt and adequate resuscitation. In patients with major burns resuscitation should be initiated within 2 hours of sustaining the injury. However there is no consensus on the type and rate of flow. Most formulas, including the Parkland formula, recommend an infusion of crystalloids at 3 - 4 ml/kg/% burn (maximum burn size 50%) during the first 24 hours. More fluid may be required in the case of associated injuries, electrical burns, inhalation injury, neonatal burns, delayed resuscitation and in young children where maintenance fluid should be added to the volume infused. It must be re-emphasised that the calculated volume is only a guideline and accurate fluid replacement can only be determined by assessing the response and monitoring vital signs and urine output (1 ml/kg/hour).

Inhalational injury

Evidence of an inhalation injury can be found in 4 - 35% of victims, depending on the age and circumstances of the injury. It remains a primary determinant of burn mortality (up by 50%). An analysis of 80 consecutive children with inhalation burns revealed the following: the offending agents were hot liquid inhalation, anoxia, carbon monoxide and cyanide poisoning. Stridor, dysphonia, singed hair, and carbonaceous sputum were physical findings of concern. Onset of symptoms was delayed for up to 48 hours. Diagnostic techniques such as fibre-optic bronchoscopy were used to document the injury and improve surveillance. However these descriptive findings did not have predictive value for injury prevention. Chest radiography, on the other hand, was not a sensitive means for early detection of inhalation injury. Aerosolised heparin used occasionally helped to loosen tracheal and bronchial casts. When ventilation was required, high-frequency ventilation was the method of choice to improve oxygenation and decrease the risk of iatrogenic lung injury. Tracheostomy, to secure an open airway, was seldom required. Surprisingly few children developed residual symptomatic pulmonary impairment.

Fluid resuscitation

The ‘Rule of Nines’ and the Lund and Browder charts are the most commonly used methods to determine burn size. However over- and underestimations are common, leading to major errors in fluid resuscitation. As a quick reference, the patient’s open hand represents 1% of the TBSA. A new ‘surface area graphic evaluation’ (SAGE) method visually diagrams a patient’s injuries and automatically generates TBSA, calculates the Parkland resuscitation fluid volume and the percentage of partial and deep burns (www.sagediagram.com). Utilising such a method will eliminate many of the inherent errors of standard methods and techniques.

It is imperative to remember that all these methods remain only estimates to initiate fluid replacement and that survival depends greatly on prompt and adequate resuscitation. In patients with major burns resuscitation should be initiated within 2 hours of sustaining the injury. However there is no consensus on the type and rate of flow. Most formulas, including the Parkland formula, recommend an infusion of crystalloids at 3 - 4 ml/kg/% burn (maximum burn size 50%) during the first 24 hours. More fluid may be required in the case of associated injuries, electrical burns, inhalation injury, neonatal burns, delayed resuscitation and in young children where maintenance fluid should be added to the volume infused. It must be re-emphasised that the calculated volume is only a guideline and accurate fluid replacement can only be determined by assessing the response and monitoring vital signs and urine output (1 ml/kg/hour).
There is an attractive alternative for intravenous resuscitation based on the tested concept of oral rehydration for diarrhoeal disease. The discovery of the glucose/sodium cotransport system in the early 1960s has provided the basis for the development of oral resuscitation methods. Essentially, sodium is absorbed from the lumen of the small intestine by three basic mechanisms. Sodium moves down an electrochemical gradient, and is exchanged for hydrogen. In addition, chloride is exchanged for bicarbonate in an active coupled mechanism. Sodium absorption is also coupled to glucose and other small ions (e.g. amino acids). The co-transport mechanism remains intact during the early phases of hypotension and mucosal injury resulting from enteric infections. Intestinal sodium absorption is critical for fluid homeostasis since water transfer is always passive and occurs secondarily to the osmotic gradient created by the movement of sodium ions during this process. This process has made possible the effective introduction of an oral rehydration method using a balanced sodium glucose solution in burns up to 40% TBSA. It is most effective if started within 2 hours of the burn. The total volume, i.e. resuscitation and maintenance fluid, is divided by 24 which constitutes the hourly administered volume. Resuscitation is initiated intravenously with a balanced crystalloid solution (Plasmalyte B) with simultaneous commencement of enteral resuscitation (ER) at a volume of 1 ml/kg/hour. The enteral feeding consists of a commercial polymeric infant formula and is administered through a transpyloric naso-jejunal feeding tube.

The enteral fluid volume is increased incrementally every 3 hours by 50% (2 ml/kg), 33% (3 ml/kg), 25% (4 ml/kg), 20% (5 ml/kg), and 17% (6 ml/kg) respectively until the calculated hourly volume is reached. At the same time the intravenous volume is correspondingly decreased until the total calculated hourly volume is administered enterally. The intravenous line is kept open with 5 ml/hour until the end of the 48-hour resuscitation period. This method has been introduced in burn resuscitation programmes at Red Cross Children’s Hospital and the Shriners Burns Unit in Galveston. A critical additional advantage of early enteral resuscitation and feeding is the amelioration of the hypermetabolic response to trauma. In a prospective clinical trial, 11 early enteral feeding resulted in a significant anabolic effect on metabolism, with higher concentrations of insulin, insulin/glucagon, ratio, higher insulin-like growth factor 1 (IGF1) and lower cortisol and growth hormone levels. In addition, it increases intestinal blood flow and results in improved maintenance of gut barrier integrity. Absolute contraindications for enteral resuscitation are a shocked patient, bowel ileus, obstructions or concomitant bowel disease. Successful introduction of enteral feeding can also be used to circumvent the long periods of nil per mouth (NPM) during frequent visits to theatre, which directly cause major nutritional deficiencies (protein and caloric). Once enteral feeding has been established and the feeding tube is beyond the pylorus, enteral feeding can be given up to 2 hours before surgery and once surgery has begun (in a stable patient) intraoperative feeding can be restarted.

**Intraoperative feeding**

Frequent operative procedures and long periods of NPM may prove very difficult to replenish in the short term. To overcome this, intraoperative feeding, although controversial, is steadily being introduced into burn care. Intraoperative feeding can be contemplated for patients who return frequently to theatre, provided there is radiological evidence that the feeding tube is transpyloric and the patient haemodynamically stable, without ileus or any other contraindication to enteral feeding. Gastric backflow with accumulation of intragastric volumes and possible aspiration can be safeguarded against with a nasogastric tube *in situ*. This method has been utilised successfully during major excisions and dressing changes in theatre.

**Emergency measures**

A question often asked is whether the effects of a burn wound can be ameliorated by emergency methods. Thermal injury of skin causes tissue damage within seconds if the temperature exceeds 54°C. Intradermal temperature remains above baseline levels for long periods – causing thermal tissue destruction to continue up to 8 hours post burn. Apart from removing the source of energy, two methods have been shown to have a significant influence on the outcome of the injury. Using a porcine model, it has been shown experimentally that the application of cold water at 16°C for 20 – 30 minutes rapidly neutralises the elevated intradermal temperatures to levels below 25°C, thereby lessening the effects of high intradermal temperatures. This results in more superficial wounds and more rapid healing. The application of hydrotherapy can still be effective as long as 3 hours post burn. 12

Ice water applications have a very deleterious effect on wounds. However cold water can be replaced effectively by a single application of a *malleleuca alterniflora* burn wound dressing (*Burnshield*) applied topically for up to 6 hours. 10 An additional advantage of cooling the burn wound is the very effective analgesia obtained in this way.

**Infections**

Despite major advances in therapy, infection remains the leading cause of morbidity and mortality for patients with extensive burn wounds. Burn wound infection is defined as 10³ colony-forming organisms (CFOs)/g eschar. Infected wounds heal slowly and may lead to systemic infections, especially if the intra-eschar organisms exceed a count of 10⁷ organisms/g of eschar. By utilising the Walker Burn Wound Model, the pharmacodynamics of the efficacy of topical application of antimicrobials can be established. 8-24 Povidone iodine has a bacteriostatic therapeutic life of 4 hours following a single topical application, mafenide acetate 12 hours and silver sulphadiazine (AgSD) 1% up to 36 hours. The therapeutic effect of topical antimicrobials is therefore of limited duration, and they must be re-applied repeatedly. Despite the initial success with antimicrobials and early surgery to reduce burn wound sepsis, resistant organisms have become very prevalent. These include fungi, acinetobacter, enterococcus, pseudomonas, fusarium and MRSA. To counteract these infections new agents have been developed, including ointments, creams and biological and non-biological dressings. New agents include antimicrobials, i.e. 0.025% NaOH, a combination of mupirocin and chlorhexidine (universal antimicrobial), a moisture-retentive ointment and colloidal or nanocrystalline silver dressings.
Nanocrystalline silver (Acticoat) is the ‘new kid on the block’. Following application it continuously liberates 50 - 100 ppm Ag++, i.e. > 10 x minimum inhibitory concentration (MIC) for most organisms. Applications can be renewed every 3 - 5 days and it has been shown experimentally to decrease the inflammatory changes in the skin, decrease tumour necrosis factor and convert cell death to an apoptotic method. The antibacterial effect has been substantiated in practice. Once the period of resuscitation has been completed, children can be sent home with Acticoat as a single topical agent. Wounds up to 30% TBSA can now be treated effectively on an outpatient basis.

Healing of burn wounds does not differ from healing of other types of wounds and general principles should apply. However there is experimental evidence that good hydration is an important external factor responsible for optimal wound healing. To optimise wound healing, therefore, the best topical agent should be chosen suitable for the particular characteristics of the wound. The antibacterial effect and ‘normalisation’ of burn wound healing has opened new avenues of treatment.

**Burn wound excision and reconstruction**

Surgical management of burn wounds has changed substantially in recent years. Early excision and grafting has led to improved mortality rates, reduced pain and infective complications, reduced number of operative procedures, amelioration of the hypermetabolic response, decreasing incidence and severity of hypertrophic scarring, joint contractures and stiffness, excellent rehabilitation and shorter hospital stay. However progress in burn surgery is hampered by a lack of data. The recent surge in biotechnology has resulted in the development of new products useful in the management of burns. Autografting with cultured keratinocytes is considered a major advance in modern burn care. This emerging therapeutic strategy can be life-saving for patients with massive burns. Cultured keratinocytes are available either as epithelial sheets or as cell suspension. Cell sheets require 3 weeks’ cultivation, are fragile, difficult to handle and prone to mechanical disruption, with only a 20 - 80% take. Cell suspension, on the other hand, is available within 5 days (1 cm² can be expanded to cover a 500 cm² area). These keratinocytes are present in a non-confluent phase and once sprayed on, proliferate and migrate. They also express integrins which are responsible for cell adherence to basement membranes, ensuring that a high percentage of these cells adhere, proliferate and mature as autologous epithelium. Epithelialisation then takes place. A deep second-degree burn, with limited donor sites, is the ideal wound for this technique.

Blood loss during excisional procedures can be minimised by the topical application of 1/30 000 adrenaline solutions, cautery or lidation of bleeding points, the subeschar injection of very diluted (1/30 000) adrenaline, the use of a tourniquet or rapid excision down to fascial levels. It is best to secure haemostatic control following 10 - 100 cm² excision before proceeding with any further eschar excision. The immediate application of procured auto- or allografts also helps to reduce bleeding from a multitude of small vessels.

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**Graft adherence and fixation**

Following graft placement on a viable non-infected recipient bed, graft adherence to the wound surface is critical, especially in anatomically mobile areas. Apart from staples and fibrin glue, an array of contact media including Hypafix have been used to secure graft adherence. Vacuum-assisted closure (VAC) methods can also be used, especially on uneven mobile surfaces and to secure dermal substitutes.

**Outcome**

As a burn surgeon, one has to ask the question: has medical expertise in terms of survival not progressed beyond the ability to reconstruct and rehabilitate? There are many survivors...
of severe burn injury, many with a meaningful quality of life. However they are forever scarred as the injury is welded to their bodies. Many victims therefore struggle with the reality of disfigurement, disability, and suffering. Successful rehabilitation, physical and psychosocial, may take 10 - 15 years in growing children. Many internal and external factors will determine the ultimate outcome. Physical quality of life can improve substantially, provided that the child remains in sound health, a multidisciplinary team looks after him/her, and the integrity of the family unit is secured. Reconstructive and cosmetic procedures must remain realistic and practical and be done at the appropriate time. In South Africa, with limited rehabilitation facilities, the successful functional and psychological recovery of burn victims remains elusive.

Conclusion

Most advances in burn care are based on basic, experimental, clinical and applied research. The results have played a major role in the treatment of thermal injuries and their sequelae – reinforcing the absolute need for research. Without this, treatment will become stagnant, with no progress. Our patients deserve better. Research has many disappointments. What is needed is an excellent study design, proper controls and scientifically valid interpretations.

My professional career was influenced by men like D. J. du Plessis, J. H. Louw, C. H. Derksen, K. Franz, C. A. R. Schulenburg, J. A. van Wyk, S. Cywes, J. Jacobs and M. R. Q. Davies. Individually and collectively they have taught me the horizon.

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