Air-Fluidised Care (AFC) - developed and evolved to alleviate suffering of patients in need

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Introduction

As always has been the case, and most likely always will be, man has to cope with external forces exerted on the human body. One can almost say: ‘that’s a fact of life’. In the movie ‘Coma’ (1978), based on Robin Cook’s novel, criminal doctors deliberately induce brain death and resultant coma in young healthy people. The ‘patients’ - now used as donors for trading their tissues and organs - are consequently transported to a long-term care facility, the ‘Jefferson Institute’, where their bodies are kept suspended by metal wires drilled through the bones of their wrists and ankles to prevent pressure injuries that would otherwise jeopardise the conservation of ‘the donor tissues’. In another movie, of the science fiction type, a wealthy yet quadriplegic business person is placed in a bed with its surface covered with tens-of-thousands of metal pins, their heads providing a warm and smooth, constantly and dynamically adjusting surface to perfectly align with the body’s contour and movements. The fate and financial possibilities of the rich and famous, for example ‘Superman’ Christopher Reeve (1952-2004), who died from the consequences of a pressure ulcer, occasionally precede renewed awareness for pressure injuries (Bisbee, 2020).

Air-Fluidised Care (AFC) is experiencing an unexpected resurgence because of the Covid-19 pandemic in 2020. The physiological parameters during mechanical ventilation in Covid-19 patients are more advantageous when the patient is placed in prone position. As this poses the patient at risk for pressure injuries in loci, other than expected in the usual supine position of critically ill patients, AFC is currently evaluated in many hospitals as an intervention worth (re-) exploring for this purpose. As AFC (introduced as Air Fluidized Therapy; AFT) was originally developed for the prevention but also treatment of severe wounds, this paper discusses the history and evolution of this technology in health care and its potential to be deployed more widely than just for the niche of the 'worst case scenario'.

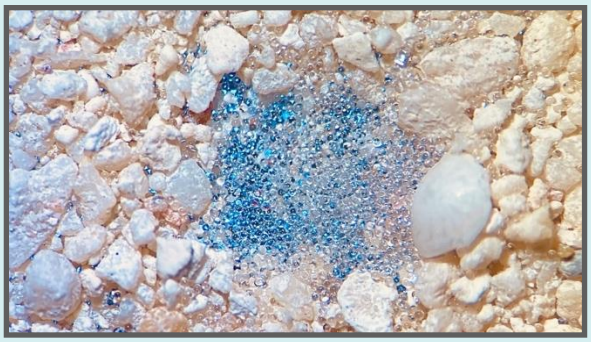

Figure 1

Medical grade glass beads, courtesy Synergie BV the Netherlands, were deposited in the center part of the picture. Although the beads are clear in color, the backlight in the picture makes them appear to be blue. The sand/seashell remnants were taken from Mambo beach Curaçao - Dutch Antilles. Image taken with an Apple iPhone SE through the eyepiece of a Leica Zoom125 stereomicroscope using a PLAN-APO objective 0,63x. Original magnification approximately 32x.

The technology : Air Fluidised Care (AFC)

In their 1969 paper 'A new concept in patient care: the air-fluidized bed', Hargest and Artz specifically aim to meet the needs of nurses with their new invention of creating a flow of air through a box (bed) filled with tiny (75-125 microns, Fig 1) spheres (beads) of medical grade glass. As a result the glass spheres act as a 'dry fluid'. At the time, their concept is not entirely new; an already existing bed named 'The British Hover' suspends patients by the flow of an excessive amount of air with the disadvantage of a significant drying effect on the skin and tissues of the burn patients where it is utilised. The air-fluidised bed of Hargest and Artz adds the beads to the equation resulting in a technology that now uses only 5% of the amount of air needed for the 'Hover bed' to function, eliminating the drying effect previously described (Hargest and Artz, 1969). Upon introduction of the technology in the early 1970s, the system was called 'hover-bed' or 'sand-bed'. One clearly gets another idea when looking at Figure 1, depicting the fine size of the glass spheres relative to the course sand- and seashell grains which can be found on beaches throughout the world. In evaluating early reports readers are encouraged to appreciate the fact that, at that time, the current feature of conditioning of the microclimate is yet to be introduced. Another issue, raised early after introduction of Air-Fluidised Care, is the amount of insensible fluid loss that appeared to be higher in Air-Fluidised Care than in other low

air-loss mattresses. The consequent weight loss is more profound in higher skin temperature (Lachenbruch, 2010). In healthy subjects (n=25) AFC is shown to decrease the skin hydration of the stratum corneum, possibly preventing moisture-associated ulceration. By reducing the pressure at the skins' surface, and managing the micro-climate, both pressure- and moisture-associated ulceration can be prevented (Denzinger et al, 2020). Early work is obviously concerned with the accumulation of microbes in the system, as for optimal results, patients are positioned onto a monofilament polyester filter sheet that separates the bodily surface of the patient from the moving spheres in the system. Wound fluid, perspiration, urine and fecal matter are often contaminated, placing the system at risk of aggravating the microbiological consequences of pro-longed contact with these excreta. Sharbaugh (1971) demonstrated AFC to be bactericidal and fungicidal due to its high acidity and the property of the medium (both spheres and movement) to sequestrate (encapsulate) and desiccate (inactivate) the microbes and organic particles, which then aggregate and sink to the bottom of the system. Although contradictory findings have been reported in heavily infected burn patients (Scheidt and Drusin, 1983), it has been shown that Air-Fluidised Care is capable of rapid clearance of common pathogens such as *Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus* (Sharbaugh, 1973).

> **"Air-Fluidised Care outperformed the conventional surfaces in healing time, patient comfort, and pain relief in large pressure injuries"**

Clinical experience

The ability of AFC to distribute interface pressure can be measured in healthy volunteers. In one such study, heel pressure appeared to be higher than acceptable and was attributed to the covering sheet possibly preventing true floating of the anatomical site (Allen et al, 1993). Also in healthy volunteers (n=25), Rothenberger et al (2014) tested blood flow (laser) and haemoglobin (white light) in the sacral and heel area while placed on various pressure relieving surfaces (standard surface; visco-elastic foam, and AFC). All devices were able to maintain sacral microcirculation compared to a hard surface serving as control. Only Air-Fluidised Care maintained microcirculation in the heel area of the subjects, which could possibly explain inadequate use of the covering sheet in the volunteers reported by Allen et al (1993). In a case series (n=5) of patients with suspected deep tissue injury (sDTI), early utilisation (within 12 hours of admission) of AFC, together with routine repositioning was reported to be able to have limited or prevented progression of tissue damage and promoted healing of the sDTI. The authors argue that progression of sDTI to a full thickness wound is considered hospital-acquired, placing the hospital at risk of cuts in the reimbursement for the auxiliary care for the injury (Allen et al, 2012).

An early randomized controlled clinical trial (RCT) in 65 patients, comparing AFC to conventional pressure relief surfaces (alternating air mattress and foam covered mattress) showed Air-Fluidised Care to be five to six times outperforming the conventional surfaces in healing time, patient comfort, and pain relief in large pressure injuries (Allman et al, 1987). In various clinical circumstances, ranging from burns, multiple trauma, pressure ulcers, external fixation and

cancer patients (specifically those with bony metastases) the fluid support and envelopment of the body in Air-Fluidised Care was found to significantly reduce shear, friction, pressure and mechanical stress to the skin and the subcutaneous tissues (VanGilder and Lachenbruch, 2010; Klitzman et al, 1998). In severe burn patients researchers found better survival in AFC treated patients than in those not treated in AFC, even considering the fact that those treated in Air-Fluidised Care had more severe burns (Nickl et al, 2020). Air-Fluidised Care facilitates nursing the patient in supine position at all times, which renders the patient better oriented to the surroundings (Scheulen et al, 1986). These findings seem to be in concordance with the notion that the quality of nursing care is a strong determinant of survival and the prevention of complications in severely traumatised patients (Shore-Myers et al, 1985). In a 13-year retrospective study, the care for toxic epidermal necrolysis (TEN) patients (n=27) was evaluated; the workers found Air-Fluidised Care to outperform standard surfaces significantly in terms of rate of re-epithelialisation (100% vs 56,3%); time to complete reepithelialisation (13 days vs 21 days) and the occurrence of complications (18% vs 75%) including cutaneous infections. Air-Fluidised Care also performed better in terms of pain reduction (Xia et al, 2016). In immobilised and undernourished patients due to different aetiologies, increased skin perfusion and more speedily formation of granulation tissue was seen during Air-Fluidised Care, aiding the healing process and reducing pain (Lucke, 1985). In the nursing home setting, Ochs et al (2005) found significantly greater healing rates in Stage III/IV pressure injuries treated with Air-Fluidised Care compared to conventional support surfaces, a finding also reported by Thomas (2001) and advised to consider the relative benefits of Air-Fluidised Care by the EPUAP/NPIAP/PPPIA (2019). In their guideline, the American College of Physicians accepts Air-Fluidised Care as being superior to other support surfaces, the comparator mostly being a standard hospital bed (Qaseem et al, 2015; Smith et al, 2013). Some reports exist where equivalence of different pressure relieving systems is suggested (Bansal et al, 2005), or the performance of more conventional systems is claimed to outperform AFC (Timsit et al, 1991; Colin et al, 2012; Fleck et al, 2010). Possibly the often small amount of subjects in the studies and the difficulty in equalising the subjects in different arms of study contribute to these conflicting findings. It appears to be beyond doubt that the many positive findings in using Air-Fluidized Care in various clinical circumstances in decades places this technology in a categorie of its own. In the home care setting, Strauss et al (1991) found the use of Air-Fluidised Care at home to be more desirable for the patient, and leading to less in-hospital days and less usage of resources. In paediatrics, Iazzetti (1987) reported the successful usage of Air-Fluidised Care for a 2-month old child admitted with severe diarrhoea. Although anecdotal, the reporting nurse was, from her experience, confident that the treatment and healing of the child was much faster due to the use of AFC. Table 1 depicts the various clinical circumstances where Air-Fluidised Care has been used successfully.

In conclusion, the sudden increase of the use of AFC in critically ill Covid-19 patients on mechanical ventilation in prone position in the ICU, is addressed. As the world is currently learning how to best treat these patients, not all is as yet clear and known. Kesecioglu (1997) reported how therapy-refractory hypoxaemia could be successfully treated by mechanically ventilating the patient in prone position,

a finding also reported by Hodgson et al (2013). By using Air-Fluidised Care for these patients, potential complications could be significantly reduced. Even in non-intubated patients, or awake, prone positioning can potentially prevent patients from transfer to ICU (Paul et al, 2020). As not all is already certain, workers are urgently requesting for conducting a meta-trial of running studies (McNicholas et al, 2020).

Table 1 Reported beneficial clinical effects of AFC treatment

Author(s)	Year	Indication
Scheulen JJ et al	1986	Burns; donorsites; recipient sites
Kesecioglu J	1997	Prone position during mechanical ventilation
Iazzetti L	1987	Pediatric case study
Sharbaugh RJ et al	1973	Spinal injuries; burns; comfort during labor
VanGilder C et al	2010	Burns; Pressure Ulcers; trauma; ext fixation; cancer (bony metastases)
Nickl S et al	2019	Severe burns
Allen L et al	2012	Suspected Deep Tissue Injury (DTI)
Xia W et al	2016	Toxic Epidermal Necrosis
Allman RM et al	1987	Large Pressure Ulcers
Ochs RF et al	2005	Cat III and IV Pressure Ulcers
Lucke K et al	1985	PU; burns; posterior grafts; donor areas
Shore-Myers et al	1985	Multiple Trauma case study

Discussion

In 2019, the National Pressure Ulcer Advisory Panel (NPUAP) formally changed its name to National Pressure Injury Advisory Panel. As 'Injury' offers 'less place to hide' and more easily implies 'guilt', legal consequences are to be expected in the future (EPUAP/NPIAP/ PPPIA, 2019). Alvarez et al (2002) reported about the most vulnerable part of the population in long term care facilities as 'the frail population", being more at risk for preventable harm like pressure injuries. This segment of the population is increasing more profoundly than the younger 'strata' in the population as a whole. It has even led to new denominators like 'octogenarians' and 'no-nagenarians' for the 80+ and 90+ segments of the population respectively. In 1998, forensic experts prospectively examined over 10.000 deceased subjects over a 1-year period and found 11,2% having pressure injuries.

Physicians seem to pay little attention to the potentially fatal outcome of pressure injuries and this condition is clearly underreported, the authors argue (Tsokos et al, 2000). It seems that the use of Air-Fluidised Care is specifically established in the acute care facilities, hospitals. Within hospitals, it appears that this technology is used exclusively in the ICU or other departments where professionals take care of the most critically ill patients. But pressure injuries, like any other wound type, are present throughout the entire health care system. Why is it, that this technology hasn't 'made it to the top'? Why hasn't it reached a position, where every patient at risk is privileged by being placed in a near-pressure-less zone, like in the movies?

Clearly, patients deserve the best possible intervention, if only because our textbooks say so: 'Air-fluidized surfaces

are considered to be the best surfaces for equalizing pressures across the entire body and reducing soft tissue shearing, heat, and moisture on the skin' (Sussman & Bates-Jensen, 2007). Or: '... As the body sinks into the fluid, additional surface becomes available for weight bearing, body weight per unit area is decreased, and there is less pressure on the body parts...' (Hinkle & Cheever, 2018). Or, better still, how this translational technology was introduced in The Lancet back in 1973: 'Given all these undesirable conditions, pressure sores can be prevented by the diligence and the considerable physical effort of a number of nurses. But now technology exists which can prevent them' (Editorial, 1973). A medical technology that prevents damage from even occurring, deserves to be utilised in a much wider set of circumstances than 'just in whatever niche'. Perhaps Air-Fluidised Care ended up in its niche because of perceived characteristics like 'too expensive'; 'too heavy to handle' or 'this is the only solution left when you end up in the worst case scenario'. But perhaps these aren't all just 'perceptions'. Perhaps, as happens more often in medical industry, in cases where there's only one supplier of a technology. The supplier then has all the revenue of the product or technology, not necessarily driving or motivating the company to continue innovating.
Then, perceptions can become reality and perpetuate themselves into the future.
Or perhaps it is a matter of responsibility and accountability. Perhaps Thomas Hargest and Curtis Artz (1969) were right the first time in addressing nurses with their new technology.

What would have happened if nurses would have taken up the responsibility for this technology? What would have happened when they would be fully responsible and accountable for the use of this device, instead of hospital administrators, managers, or health care insurers, or even doctors? What have doctors done to grow the 'playing field' for this technology? Doesn't the large amount of positive clinical experiences of health care professionals discussed in this paper warrant a larger, wider, broader usage of Air-Fluidised Care? Returning once more to the company currently responsible for this technology. Over the past twenty years the company currently responsible for this technology, according to its own mission and vision, has listened to their customers, the nurses as end-users of their products and technologies. They have innovated their product to accommodate more space at the arms-region of the patients body. They have built in full climate control of temperature and humidity. They have installed height-adjustability as a standard feature in their product, a dimmed blue light for night vision, not disturbing the patient but accommodating the professional. The company has listened when professionals requested for the motor unit to be removable so it can be placed more distant to the patient room. Air-Fluidised Care is now a fully developed medical intervention capable of alleviating the suffering of patients when their tissues are most vulnerable. Because of the variance in support surfaces and adjacent factors, the positive role of Air-Fluidised beds has not always been evident.

The published evidence discussed in this paper supports the observation that Air-Fluidised Care can be utilised to significantly reduce the burden and suffering of pressure injuries to the patient.

It also underpins the notion that Air-Fluidised Care allows the caregiver to regain control. This technology deserves its place in all fields of health care where 'no pressure' is warranted. As so well put by wound expert Jacqui Fletcher in 2006:

> **'The costs of treating a patient who develops a pressure ulcer, far outweigh the costs of prevention'**

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