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# Cardiodynamic adjustments in skilled civil aircraft pilots while unexpected emergency conditions appeared during a simulated flight within a homemade Airbus A300 cockpit

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# Cardiodynamic adjustments in skilled civil aircraft pilots while unexpected emergency conditions appeared during a simulated flight within a homemade Airbus A300 cockpit

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**Abstract**. To highlight which cardiodynamic adjustments take place in civil aircraft pilots when unexpected mechanical accidents occur while they are in flight, in 8 skilled pilots we detected the mean blood arterial pressure (MAP) and heart rate (HR) while a unexpected failing of one engine occurred when they were engaged in a simulated flight with a homemade Airbus A300 cockpit. Comparing these two cardiovascular variables in a simulated flight test, just as when the accident happened, together with the values assessed in a simulated control flight without accidents, by the non-parametric Wilcoxon test for paired data it has been found a significant increase of MAP's median (+ 20.3%, P = 0.008) without significant increase in HR one. However, in several tested pilots this sudden MAP increase tended to progressively recover baseline values while simulating the flight despite the event triggering this functional response was still present.

We concluded that the cardiovascular apparatus of skilled aircraft civil pilots adapts in such a way of sudden respond to unexpected emergency conditions by adjusting mean arterial blood pressure for adequate blood flow to limb muscles, and this happens without a concomitant tachycardia response in order to maintain an optimal mechanical/metabolic efficiency of the heart.

**Key words:** flight simulation by homemade aircraft, aircraft engine fail, mean arterial blood pressure, heart rate, specific pilots cardiodynamic adapting

## 1. Introduction

Over the past years there have been several reports concerning civil pilots dead during flight due to serious cardiovascular events [1]. About that, in a group of pilots which were several months banned to fly since covid-19 lockdown and which simulated manoeuvres to takeoff, flying in route and landing, a previous study showed that in route mean arterial blood pressure (MAP) stayed at a mean value of about 104 Torr or 12% higher than expected [2]. It is worrying that these high MAP values have been related to significant micro-circulatory brain damage found by brain NMR imaging [3].

To highlight which cardiodynamic adjustments take place in these pilots when unexpected mechanical accidents occur while they are in flight, in this experimentation we detected in a group of skilled pilots the MAP and heart rate (HR) values while a unexpected failing of one engine occurred when they were engaged in a simulated flight with a homemade civil aircraft cockpit.

## 2. Methods

In this study 8 skilled civil aircraft pilots (45±12 years, 8230±4310 flight hours) undertook a medical check in order to ascertaining the absence of psycho-physical conditions not compatible with the planned experimentation. The study is conformed to the standard set by the latest revision of the Declaration of Helsinki and prior to testing, recruited participants provided written informed consent.

The flight simulator was the cockpit of an aircraft Airbus A320 entirely homemade built by the 3D Aerospazio Srls, at the Department of Environmental Civil Engineering and Architecture, Cagliari's University, perfectly simulating, both structurally and functionally, the original one (Figure 1).

The experimental protocol consisted in the simulation, carried out by crews formed by the Commander and the First Official, of a flight plan that provided for the takeoff from the airport of Elmas-Cagliari, in Italy, and then to follow a south-East route going in the direction of the Cape Carbonara of the Sardinia island, and reversed the route to land in the same airport. The average duration of the flight was about 20 minutes, and it was repeated two folds by each driving crew since, randomly, in one of these was unexpected simulated a failing to one engine just when the aircraft was climbing towards the scheduled in route altitude. Among the two flights a 30 min of interval was done. During all phases of the route, a third pilot, positioned outside the cockpit, simulated the personnel of the Cagliari's airport control tower being in constant radio contact with the crew of the Airbus A320 simulator.

**Figure 1.** Panoramic photo of the interior cockpit of the Airbus A320 aircraft simulator were is shown the driving crew engaged in the flight simulation. Notable is the cuff of the sphygmo-manometer, connected to the left arm of the firs pilot and manoeuvred by the physician just seated behind his seat.

Both systolic (SAP) and diastolic (DAP) arterial blood pressures together with HR were recorded by means of an automatic brachial sphygmomanometer (Omron X3, Hoffman Estate, USA). The MAP was also obtained as the DAP + 1/3 (SAP + DAP) [4]. Starting from a $t_0$ time corresponding to the time of aircraft takeoff, a skilled physician positioned behind the driver's seat (see Figure 1), turned on the Omron X3 for acquisition of SAP, DAP and HR values which were referred to another operator who wrote down the time of all the relevant events that occurred during the flight. These cardiovascular measurements were repeated as frequently as possible during the simulated flight as this was not always possible for unpredictable movements of the arm in which the inflatable cuff was wrapped invalidating these acquisitions.

## 3. Results

As an example, graphs in Figure 2 clearly show the dramatic and reciprocally occurring changes in both HR and MAP of a typical tested pilot, happening just when the engine fall occurred. It is also of any interest to highlight, in these two hemodynamic variables, the progressive derive towards more attenuate values while the damaged aircraft continued its flight up to landing.

Box and whiskers plots in figure 3 show that the interquartile for MAP values assessed in the flight while a failing engine happened ($MAP_{fe}$) ranged from 101.5 to 145.5 Torr with a median value of 118.5 Torr. Differently, in the normal flight ($MAP_n$) the interquartile range was from 95.5 to 102.5 Torr, practically almost without any overlap on the $MAP_{fe}$ one. Moreover, the $MAP_n$'s median value was of

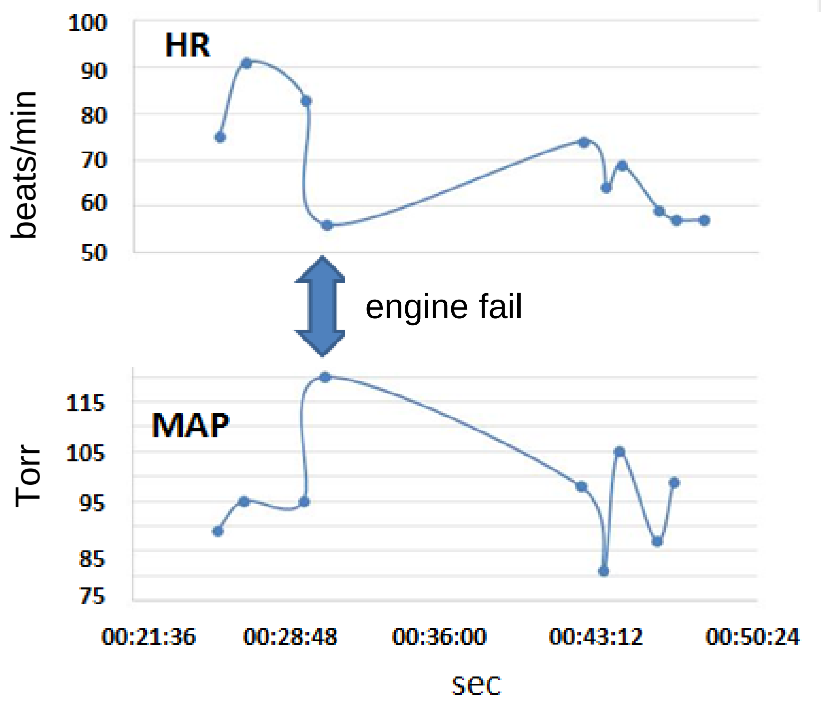


**Figure 2.** Graphs show, in a typical tested pilot, heart rate (HR) and mean arterial blood pressure (MAP) measurements (blue filled circles) taken during the time of the simulated flight in which an engine fail occurred. Land time: 00:41:32 h.

98.5 Torr which means that, when the engine fail occurred, the median of the distribution increased of 20.3% with respect to what happened, at the same flight time, in the $MAP_n$'s test.

To show possible statistical difference among these two groups of cardiovascular data ($P<0.05$ was considered as significant), due to their non parametric distribution we utilized the Wilcoxon test for paired data [5] (MedCal statistics package, Belgium) which showed a $P=0.008$. So, the simulated engine fail occurring while the aircraft was climbing towards the route altitude gave rise to a pilot's MAP increase which was of 27% out from that expected stated value at 93 Torr.

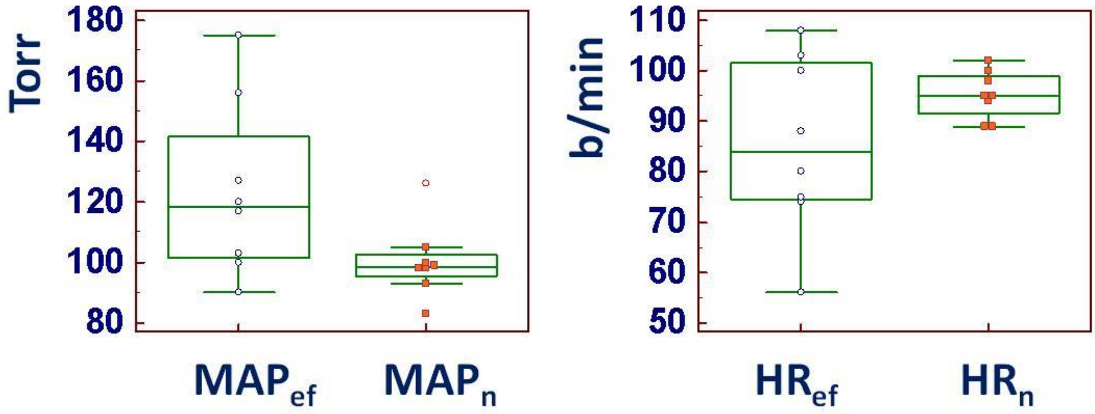


**Figure 3.** On the left, box and whiskers plots represent mean arterial blood pressure values (MAP) assessed in each of the 8 recruited pilot when an engine failing occurred (ef) while flying: empty blue circles, and when the flight was normal (n): red filled squares. On the right, box and whiskers plots represent heart rate values (HR) also when an engine failing occurred while flying (ef) and when the flight was normal (n).

Concerning the plots on the right of figure 3, interquartile limits for heart rate values assessed in the flight while a failing engine happened ($HR_{fe}$), ranged from 74.5 to 101.5 b/min with a median value of 84 b/min. This latter interquartile entirely contains the one concerning the heart rate values assessed in the normal flight ($HR_n$) which ranged from 91.5 to 99 b/min with a median of 95 b/min. The Wilcoxon test for paired data, applied to HR values, showed a P=0.25 among the two flight data, a value which was not statistically significant. So, it can be stated that the failing engine did not produce variations in HR distinguishable from those observed in flight without accidents.

## 4. Discussion

The here presented experimental data show, in our tested pilots, a dramatic cardiovascular response to an unexpected, albeit simulated, event such as an aircraft's engine failure. The aim of this circulatory response was that of adequate the cardiac output to the increasing oxygen delivery; this for meet the actual power output from limb muscles [6]. In fact, due to the lack of a motor, the aircraft autopilot was excluded with the need of fly the aircraft by hands and feet manoeuvres on specific handles and pedals, and this required an increase of power output in the proper limbs muscles. However, experimental data showed that this cardiovascular adjustment concerned only the hemodynamic modulation managed by the MAP, without significantly affecting the chronotropic modulation managed by the HR.

This observed, monotonic, pressor response to adjust blood flow demand towards limbs muscles enhancing power output, agrees to the muscle metaboreflex induced pressor response [7]. In fact, it may be that pilots contracted limb muscles while since, even though in a simulated way, they were strongly engaged in coping with the unforeseen mechanical emergency, thus suddenly increasing intramuscle pressure and diminishing, in this way, the blood flow from superficial towards central limb veins due to possible diameter constriction of perforating veins [8]. The relative stagnation of blood in the superficial venous circulation of muscle legs could induce accumulation of by-products of metabolism in muscles extra vascular space. This local hemodynamic/metabolic perturbation in our tested pilots could elicit the stimulation of muscle receptors with specific sensitivity for these substances, the so-called muscle metaboreceptors [9], which triggered sympathetic nervous reflexes targeting a MAP increase [10].

The here observed absence of an associated tachycardia could be attributed to a concurrent increase in parasympathetic tone on the heart's sino-atrial node mediated by the baroceptive reflex that could surpass the metaboreflex-induced cardiac sympathetic activation [11].

As a conclusion, from what here experimentally acquired it could be asserted that cardiovascular apparatus of skilled civil pilot of aircraft is able of properly respond to unexpected flight emergency conditions by adjusting mean arterial blood pressure in such a way of furnish adequate blood flow to limb muscles. This happens within a framework of efficient cardiovascular adaptations that limit the tachycardia response in order to maintain an optimal mechanical efficiency of the heart and allow a progressive recovery of the baseline values of MAP and HR despite that the event triggering this functional response is still present.

A limit of this experimentation could concern in the lack of any energetic measurements, in terms of mechanical efficiency, to be compared among the two flight conditions here tested in pilots. In fact, it has been found that multi-bodies models of human body could be utilized for this purpose [12]. So, the Authors intend to plan future experiments on civil aircraft pilots while flying, in such a way of implementing, among the acquired data, also those concerning the bioenergetic adaptations typical of skilled pilots.

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