Impact of high intensity transient signals on the choice of mechanical aortic valve substitutes

Joachim Laas*, Samer Kseibi, Matthias Perthel, Andreas Klingbeil, L’Emir El-Ayoubi, Aiman Alken

Abteilung für Herz-Thorax-Chirurgie, Herz-Kreislauf-Klinik Bevensen, Römstedter Str. 25, 29549 Bad Bevensen, Germany

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Abstract

Objective: High intensity transient signals (HITS) observed during extracorporeal circulation and following mechanical valve replacement are suspected of causing cognitive dysfunction (deterioration of episodic and working memory). This study evaluates the role played by valve design (bileaflet versus tilting disc) and other parameters in the incidence of HITS. Methods: Thirty patients were selected for the study as follows: 18 males, 58–78 years of age; ten St. Jude Medical, ten CarboMedics, ten Medtronic Hall (MH); all size 23, in optimum orientation (Ann Thorac Surg 68 (1999) 1069); all in sinus rhythm; no coronary or carotid artery disease; all in sinus rhythm, international normalized ratio greater than 2.5 and all at least 9 months postoperative. All patients had bilateral HITS measurement in both middle cerebral arteries via transcranial doppler for 30 min. If five HITS or more were observed during the initial 10 min, patients were subjected to 100% oxygen breathing followed by 10 min of normal air breathing. Simultaneously, HITS were measured in the right radial and femoral arteries. Results: Patients with bileaflet valve substitutes revealed HITS rates varying from 32 to 108 counts/h. There was only one HITS observed in the MH valve group during the 5 h observation period (0.2 HITS/h). There were no HITS detected in either the radial or the femoral arteries in any patient. After breathing 100% oxygen, HITS significantly decreased or completely disappeared (0–30 HITS/h). When normal air breathing was resumed HITS reappeared or increased. With an intravenous infusion of 100 mg of lysine acetylsalicylate (Aspisol®, Bayer Leverkusen, Germany), HITS decreased by 16 to 41%. Conclusions: We conclude that bileaflet mechanical valve prostheses produce HITS even in their optimum orientation. HITS following bileaflet valve replacement have an unstable nature and might be composed of nitrogen and platelets. Tilting disc valves in their optimum orientation provide almost physiological conditions with HITS measured in the same range as bioprosthesis. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

High intensity transient signals (HITS) observed during extracorporeal circulation (ECC) are known to be associated with postoperative cognitive dysfunction, especially with deterioration of episodic and working memory [1–3]. HITS are also known to occur after mechanical heart valve replacement [4–9]. Here, they gain increasing interest, since they might be associated with an elevated risk of cerebral embolism [3,10,11] or cognitive dysfunction [12]. We have previously shown experimentally in swine that HITS vary widely with design and orientation of mechanical heart valve substitutes [13,14].

Optimum, almost physiologic, results were found for the tilting disc (Medtronic Hall, MH; Medtronic Minneapolis, MN) substitute, with its large orifice facing the non-coronary aortic sinus [14,15]. Bileaflet valves (St. Jude Medical (SJM), St. Paul, MN) had their best results with one leaflet oriented towards the right and the other towards the left aortic sinus. However, the SJM could not match the almost physiological performance of the tilting disc valve in its optimum orientation [14]. In accordance with these experimental findings, we implanted tilting disc (MH) and bileaflet (SJM and CarboMedics (CM), Austin, TX) substitutes in their optimal orientation in clinical practice and performed HITS measurements.

Furthermore, in patients with elevated HITS counts, the influence of oxygen breathing and administration of 

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* Corresponding author. Tel.: +49-5821-82-1702; fax: +49-5821-81-1777.
E-mail address: prof.laas@herz-kreislauf-klinik-bevensen.de (J. Laas).
acetylsalicylate (Aspisol®, Bayer Leverkusen, Germany) was investigated. Finally, a hypothesis as to the composition of microemboli detected as HITS is suggested.

2. Materials and methods

All data were collected on a prospective basis. Prior to inclusion of patients in the study, informed consent was obtained. The first part of the study compares the results of 30 patients (18 males, 12 females, 58–78 years of age) with isolated aortic valve replacement.

For a better comparison, only patients with valve size of 23 were selected. Ten patients carried a SJM, ten a CM, and ten a MH substitute.

To avoid interference with the operative procedure, measurements were performed not earlier than 9 months postoperatively. Since carotid and coronary artery disease as well as atrial fibrillation are associated with HITS [16,17], none of the patients were allowed to suffer from these disorders as proven by duplex examination of the external cerebral arteries, by preoperative coronary angiography, and actual stress ECG.

International normalized ratio (INR) was in the therapeutic range (>2.5). All valves were implanted in optimum orientation as described by Laas et al. [14].

Fig. 1 illustrates the optimum orientation of tilting disc and bileafllet valves.

For the detection of HITS (Fig. 2), the middle cerebral artery was monitored bilaterally with 2 MHz probes through the temporal bone window (Nicolet 2 MHz probe, Nicolet, Estenfeld, Germany).

Probes were connected with a Doppler sonography device (TC 4040 Medilab, Würzburg, Germany) allowing online recording [18,19]. Only unidirectional signals within the Doppler velocity spectrum with an intensity of 3 dB HTL higher than the background flow signal and lasting less than 300 ms were counted as HITS [20].

Recording and evaluation were performed online and confirmed by visual and acoustic controls. The performance of this algorithm has been shown to be equal to that of some human experts and only slightly below the mean performance of a panel of human experts [19]. All signals were saved on hard disc.

HITS were recorded in both cerebral arteries for 30 min. If five HITS or more were observed during the initial 10 min, patients were subjected to 100% oxygen inhalation for 10 min. For this purpose, to effectively minimize nitrogen content of the blood, an ASB-mode using a respirator (Evita, Dräger, Lübeck, Germany) was used.

Oxygen inhalation was followed by another 10 min of normal air breathing.

Furthermore, HITS were simultaneously measured in the right radial and femoral artery. For this purpose, a 4 MHz probe (Nicolet 4 MHz probe, Nicolet, Estenfeld, Germany) was used.

In the second part of the study, we selected another ten patients from our HITS database (eight males, two females, 51–75 years of age). All patients had bileafllet valves implanted in aortic position (four patients with valves size 23, four with size 25, and two with size 27).

After a baseline measurement of 20 min, 100 mg of lysine acetylsalicylate (Aspisol®, Bayer Leverkusen, Germany) was given by infusion over 3 min. Following HITS, recording was continued for another 40 min.

3. Results

In the first part of our study, patients with CM and SJM valves revealed HITS rates varying from 32 to 108 counts per hour. There was only one HITS in the MH group during the whole 5 h observation period (0.2 HITS/h). No HITS could be detected either in the radial or the femoral arteries of our patients.

After inhalation of 100% oxygen, HITS significantly decreased or completely disappeared (0–30 HITS/h). With normal air breathing, HITS reappeared or increased (Fig. 3).
In the second part, the ten database patients with bileafllet valves revealed 81–531 HITS/h. After administration of lysin acetylsalicylate, HITS decreased in each patient in a range between 16 and 41% (Fig. 4).

4. Discussion

The phenomena of HITS were initially observed by cardiac surgeons during operations using ECC [21,22]. There are numerous studies, indicating a correlation between HITS during ECC and neurocognitive dysfunction [1–4,16].

Off-pump surgery has been proposed to avoid HITS and their sequelae [2].

Several reports indicate that immediately after heart valve surgery, HITS can be found in almost all patients regardless of the selection of valve or operative technique [6,7].

After 6 months postoperatively, HITS rates decline to negligible levels following biological valve replacement. With respect to mechanical valves, there is a tremendous range of HITS rates varying from none or negligible up to several hundreds HITS/h [5–7,15,23,24].

We have recently shown in animal experiments that orientation of mechanical heart valves has an important impact on HITS rates. The MH tilting disc valve, when implanted in optimum orientation (large orifice facing the non-coronary sinus) showed HITS rates close to normal physiology [14,15]. In contrast, SJM valves revealed HITS in any orientation [16,15].

The present study compares CM and SJM bileaflet valves with the MH tilting disc design with respect to HITS, with all valves implanted in optimum orientation. Since atrial fibrillation, the presence of arteriosclerosis, and a history of cerebral infarction predispose for HITS, only patients in sinus rhythm without carotid or coronary artery disease and without history of cerebral vascular events were selected.

Furthermore, for a better comparison only patients with valve size of 23 were investigated.

As expected, all patients with bileaflet valves showed significant HITS. In contrast, there was only one HITS in one MH patient during the entire 5 h observation period, which shows the superiority of the tilting disc design.

It has been demonstrated by several authors that oxygen administration by facial mask could reduce the number of HITS [23,25].

In our study using the ASB-mode of respirator, HITS even completely disappeared in some patients. This suggests that nitrogen is at least a component of HITS following mechanical heart valve replacement.

The observation that HITS could not be detected either in the radial or femoral artery may be related to the distance of the place of measurement from the aortic valve which is 2.5 to 3 times longer than the middle cerebral arteries. This indicates a short life time and an unstable nature of the microemboli detected as HITS.

There are contradictory observations in the literature with respect to the decrease of HITS after mechanical heart valve replacement and the administration of lysine acetylsalicylate [24]. Our data with decrease of HITS after administration of intravenous (i.v.) lysine acetylsalicylate in each patient supports the view that thrombocytes might also be a component of HITS.

It is known from in vitro studies that on the inflow side of mechanical heart valves, there are locally extremely low pressures with peaks down to −2000 mmHg [26]. Like in the Caisson disease, a local release of nitrogen and oxygen bubbles occurs. Due to their lesser solubility, the nitrogen bubbles persist for some time in the fluid of the blood. In the presence of non-turbulent flow, like in normal, biological, and tilting disc valves in optimum orientation, these microbubbles are quickly dissolved into the fluid of the blood.

However, in the presence of turbulence, like in bileaflet valves and tilting disc valves in poor orientation, the low pressure nitrogen bubbles act like vacuum cleaners and may form aggregates with thrombocytes and potentially other activated components of the blood [27]. Some of these particles, even though unstable in nature, could reach the cerebral circulation and could be detected as HITS.

While this hypothesis seems appropriate, given the observed experiences to date, more investigation will be

![Fig. 4. Significant decrease of HITS after Aspisol®.](image-url)
necessary to exclude other possible explanations for the existence of HITS, to define their precise composition, and to establish treatment modalities that either reduce HITS levels or minimize their sequelae.

While there are some who would argue that HITS are only an interesting phenomenon without clinical consequence [27], there are others who see HITS as a possible explanation for at least some of the morbidity and mortality after heart valve replacement.

There are published studies by Kaplan and Deklunder et al., for example, indicating that a statistically significant correlation between a significant incidence of silent brain infarction and cognitive dysfunction exists [11,12].

And what of the impact on the other major organ within range of HITS, the heart?

Could microemboli in the coronary circulation be a cause of increased morbidity and mortality observed in heart valve replacement patients versus those receiving repair procedures?

References