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Psychopatho-Ophthalmology, Gnostic Disorders, and Psychosis in Cardiac Surgery

Visual Disturbances After Open Heart Surgery

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Summary. The visual disturbances of 45 patients following open heart surgery could be divided into disturbances of (1) visual acuity, (2) visual accuracy, and (3) visual reality testing.

The non-hallucinatory phenomena consisted mainly of loss of colour vision, metamorphopsias, visual gnostic disorders and cortical blindness. The hallucinatory phenomena could be divided into the delirium type of hallucinations with clouding of consciousness and the spectator type of hallucinations with a clear sensorium.

The causes of the visual symptomatology and cardiac psychoses are seen in microembolization and/or ischemic hypoxia. The basal ganglia and the occipital lobe are areas of predelection for embolic and hypoxic changes. Identical psychoses also occur in cerebral malaria and polycythemia vera which show the same embolic and anoxic neuropathological changes of vascular occlusion as do many patients who die following open heart surgery with extracorporal circulation.

Key words: Psychopatho-ophthalmology – Gnostic disorders – Cardiac psychosis – Microembolism – Basal ganglia

1 Introduction

Cardiac surgery employing extracorporal circulation (ECC) and the specific problems of vascular surgery still provide an involuntary experimental mechanism for the study of neuropsychiatric phenomena. Various technical improvements, such as the removal of microdebris by placement of filters in the blood perfusion lines [1, 28, 54], reduction in the volume of whole blood transfusion [45] and improvements in operative technique seem to have reduced the very obvious complications which were described in the 1950's and early 1960's: *cardiac psychosis* and *cardiac delirium* and the different forms of altered states of consciousness,

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mainly *stupor* and *coma* [8, 10, 21]. The overall incidence of neuropsychiatric disorders of between 40% and 70% in the 1950's to between 10% and 30% today is still very high [19, 39].

In addition to these well recognized syndromes there also exists a neuropsychiatric symptomatology which can be revealed only through careful interviewing. In patients who appear completely normal one group of symptoms is revealed only by further questioning following a minor complaint, which initially does not suggest a major disorder. As a result of fear, a second group of patients is reluctant to admit to any mental changes. They are *dissimulating.* Repeated interviews 1 to 2 weeks after operation very often reveal psychotic experiences during the first few postoperative days, experiences which the patients would have kept to themselves if they had not been asked.

Blacher (1972) was the first to describe this type of "hidden psychosis of open-heart surgery" [7]. In a third group, patients appear to the observer to be alert and not overtly disturbed, but are in fact suffering from transient states of *acute mutism* which is related to *akinetic mutism,* which was described originally as a purely neurological disorder [15, 16], but which may also be related to *catatonic syndromes* [40]. Repeated neuropsychiatric assessment 1 to 2 weeks after surgery will additionally reveal in certain cases, striking *amnestic syndromes* for psychotic experiences and neuropsychiatric disorders which occurred during the first few days after operation. Some patients do remember their experiences of cardiac surgery, including psychotic states, years after the operation. There are others however who are completely amnestic of these episodes or who have only indistinct reminiscences. During the intitial postoperative period when they express psychopathological phenomena, they appear alert and fully conscious (oriented). If one keeps in mind the special role of dreaming and allied states of visual experiences in the course of cardiac surgery [32, 43], one is reminded of the phenomena of remembering only fragments of dreams, and of thus retaining only a vague feeling of what happened. On the other hand there is the category of vivid, impressive dreams which are never forgotten.

1.1 The Present Investigation, the Data, Incidence of Visual Disturbances After Open Heart Surgery, and Aims of the Paper

While investigating neuropsychiatric complications following cardiac surgery [39, 41] during 1972/73 and 1977/78 it became apparent that in addition to cardiac psychoses and obvious neuro-ophthalmological complications, there existed a wide spectrum of hidden neuropsychiatric syndromes which were particularly related to *psychopatho-ophthalmology.*

In the first study of 150 patients, when these latter syndromes were unfamiliar, there were 15 patients (10%) who *spontaneously* complained of some type of visual disturbance. In the second investigation of 120 patients who were questioned systematically every day postoperatively until the end of the third week, 30 of the 120 (25%) admitted to having or having had visual symptoms. The total material presented here consists thus of 45 cases, which are listed according to the main or leading symptom, i.e. 1) predominantly disturbances of visual acuity (11 cases), 2) disturbances of visual accuracy (17 cases), and 3) disturbances of visual reality

Table 1. Disturbances of visual acuity

Dimming of vision
Blurring of vision
Indistinctness of vision
Loss of colour vision
– all objects appear grey –

testing (17 cases). The aim of this paper then is to describe the different groups of symptoms and to relate them to other psychopathological phenomena characteristic of cardiac surgery, and to discuss the main causative factors: embolization and anoxia.

2 The Different Groups of Symptoms

2.1 Disturbances of Visual Acuity (Table 1)

These disturbances were characterized by dimming or blurring of vision, indistinctness of vision and loss of colour vision. The patients complained mostly that they could no longer see as well as before. For example, they asked whether there was steam or hot air in the intensive care unit because the people and objects they saw, the nurses, doctors and machines, appeared shadowy. Alternatively their surroundings appeared to be in a haze. A very common metaphor was "like seeing through a veil" or "through a curtain". Some patients said that all things appeared grey, and others actually stated that there was loss of colour vision.

Psychologically the *reactions* of the patients were quite varied. A few seemed not to be overtly disturbed during the early period of investigation—1 to 5 days after the operation; they would admit later, however, when asked about these symptoms again, *that they felt queer or that all seemed to have been endowed with an intense personal significance and meaning.* Others thought from the very beginning when they complained about their visual symptoms, that things were going wrong with them. Some would admit however only to visual symptoms at the time of examination and only talked freely about their fears when everything was over, 7 to 14 days after the operation. There were, however, a few patients who later were amnestic about their original symptomatology.

This type of disturbance of visual acuity, including the psychological sequences, generally disappeared completely after 2 weeks. The causes will be discussed subsequently.

2.2 Disturbances of Visual Accuracy (Table 2)

Under this heading a group of quite different symptoms is listed. *Diplopia* was a frequent complaint. Very often the patients were not sure whether they really

Table 2. Disturbances of visual accuracy

Diplopia
Distortion of objects
- doubling of contours
- edges being displaced or cut off
- surfaces appear bent
- all things appear round
- waviness of linear components
Distortion of faces
- doubling of contours
- parts being displaced or missing
- "monster faces"
Moving phenomena
- horizontal or vertical lines may be seen moving
- objects may be seen rotating
Micropsia
Macropsia
Upside down vision

had double vision or whether the second image seemed to grow out of the object they looked at.

Another, more complex category of symptoms was apparent *movements of stationary objects:* straight lines, such as the frame of a picture, appeared to move. One patient reported that everything upon which he fixed his eyes was rotating. There was *micropsia* and (not so often) *macropsia* and the impression that things were *very far* or *very close.* There seemed to be *loss of stereoscopic vision.*

Another group of symptoms was *distortion of objects:* things and persons no longer had their normal size and shape. Typical descriptions were that edges or parts were cut off or displaced, surfaces appeared bent, or everything was round. There was also waviness of linear components. The *distortion of faces* deserves special mention. Patients complained that contours were double and that parts of a face were either missing or displaced. Heads became very large or extremely small and appeared ugly and sinister, and patients spoke of *"monster faces".*

These patients reacted similarly to the different phenomena as the first group. The images particularly of *metamorphopsias* and *kakopsias,* gave rise to intense fear. Some of the patients seemed to have a clear insight into the pathological nature of these phenomena, because they related them to the adverse effects of the operation; there were, however, others for whom they played an important role in the paranoid content of their thoughts.

In some cases it was difficult to differentiate between metamorphopsias and hallucinations. Transitions of psychopathological and visual phenomena from one category of symptoms into another is quite common in patients with cerebral involvement after cardiac surgery. There may also be an ambivalent or fluctua-

ting insight into the psychotic experience, as one patient stated later: "One part of my mind knew that the symptoms which distressed me were not real, though the periods of an awful nameless fear which I suffered were quite beyond my control... one part of my mind knew that the bear and the rods were not actually there—but I could see them" [35].

The symptoms which are summarized under the heading of "disturbances of visual acuity and visual accuracy" have not been previously described in detail as side effects of cardiac surgery, especially as isolated symptoms without other neurological deficits. Freyhan et al. [23] mentioned, besides obvious gnostic defects ("transient aphasias, alexias, agraphias and difficulties with comprehension of spatial relationships") "changes in visual capacity" and Gilman [25] noticed "a mild disturbance in the recognition and reproduction of visual patterns to a severe agnosia that is chiefly visual".

The gross agnostic syndromes will be described in the next section; attention now being focused on the type of hidden psychopatho-ophthalmology which is discovered only by careful interviewing and examination of the patient. It must be remembered that even today open heart surgery very often implies a global attack on the brain by microembolization and anoxic ischemia [40, 45, 55] which leads to a temporary disintegration of the total cerebral cortex and its motor-sensory systems. The variety of transient visual and neuro-psychiatric symptoms in the same patient sometimes show that the cortex as a whole is involved and not just a circumscribed area. The role of organicity is not questioned in cases where severe focal neurological signs indicate permanent cerebral damage. This is the case when massive air embolism or emboli of larger surgical fragments and longstanding episodes of hypoxia occur. The majority of neurological symptoms however, such as extensor responses, disturbances of sensibility and even cases of ophthalmoplegia, aphasia and other gnostic disorders may be only fleeting and transient. They disappear in the same way as do the very obvious psychopathological phenomena of hallucinations and delusions. Thus the breakdown in the neuro-physiological and neuro-anatomical systems can be of different severity and types, it is sometimes selective due to phylogenetic and anatomical reasons and to individual predispositions. This is why in cardiac surgery one can study the nature of psychological phenomena and their relationship to organic processes in the brain.

Hypoxia and microemboli also explain the variety of visual symptoms so far described. Transient diplopia, unrelated to oculomotor palsy as in our cases, has been observed in intermittent insufficiency of the basilar artery [61]. Binocular blurring of vision may also be due to embolization of the calcarine cortex by fibrin platelet fragments originating from an atherosclerotic plaque which are propelled into the calcarine branch of the posterior cerebral artery [61]. In our cases debris from calcified valves or microemboli generated through the ECC are the main sources of embolization. This explains why funduscopic examination in these patients with blurring of vision was normal. There was no pupil edema. Only when larger emboli or longer episodes of hypoxia occur in the striate area, will homonymous visual field defects be the result. There were three such cases in our material which are not evaluated in this study. Hemianoptic defects following cardiac surgery were described previously [53, 60].

Table 3. Disturbance of visual reality testing

Visual spatial disorientation
- defective localization of objects in space
Visual agnosia
- failure to recognize objects when optic pathways are intact; "mindblindness"
Prosopagnosia
Denial of blindness (Anton's syndrom)
Other agnostic syndroms
- denial of operation (anosognosia)
- time agnosia
Enhancement of normal after image
Visual perseveration (Paliopsia)
Metamorphopsia
Visual hallucinations
Delirium type (accompanied by mental confusion and disorientation)
- not highly organized: dream-like
Spectator type (accompanied by a clear sensorium)
- highly organized: images of people complex scenery

2.3 Disturbances of Visual Reality Testing (Table 3)

This is a conglomerate of two major groups of symptoms, the agnostic and the hallucinatory type of visual pathology. Cortical blindness plays a separate role.

2.3.1 The Agnostic Phenomena and Cortical Blindness

Among patients of the first group there were those who showed mainly *visual spatial disorientation.* They were noted to have difficulty in picking up objects from their bed cover or side table in that they systematically grasped a few centimeters beside or above the object; or the cup would miss the mouth, though there was no tremor. Visual spatial disorientation, which is supposed to be related to the parietal lobe [61], appeared to be basically a visual symptom. Since *amnestic symptoms* seemed to play an important role as well, it was sometimes impossible to decide clinically whether the defective localization of objects in space was due primarily to a defect in vision, in spatial orientation or the result of an impaired topographic memory.

These observations support the hypothesis of Hécaen of two different systems of visual processing, both in anatomy and function, the cortical and mesencephalic systems [31]. The phylogenetic older and common tectal visual center comprises memory, attention, and perception, i.e. the visual functions of lower animals which include detection of simple patterns, colours, and of speed. During the process of telencephalization higher, "gnostic" functions take part in visual identification, making seeing more and more an act of perceiving and finally reflective perception. In higher animals and in man however, normal vision involves an interaction of the two visual systems and both participate in different psychological categories of vision.

The relationship of gnostic to visual functions could be seen also in one case of *"Gestalt-dissolution"*. One patient was not sure whether he sufffered primarily from a defect of vision or "concentration", as he described the experience of seeing doctors and nurses *dissolved* into amorphous parts and disappearing as "points" after they were recognized at first fully and completely for a few seconds when they entered the room. Gestalt-dissolution can be thus conceived as an extreme lack of visual synthesis demonstrating the integrative function of gnostic faculties of the cerebral cortex. For perceiving our world the optic apparatus is ontogenetically and phylogenetically the oldest. This may explain why optical phenomena have such a central role for the individual in orientation in space and time. However in man this function of orientation still seems to be dependent on other gnostic functions. Representation of reality in the perceptual world depends on such features as shape, colour, movement and distance [9],– phenomena which may all be involved in cardiac surgery.

Prosopagnosia of different degree was seen in four patients: they were either unsure or not able, to recognize familiar faces. Doctors, nurses and even relatives were identified by their voices, though vision was apparently intact, because these patients could see other things. One patient, besides recognizing persons by their voices, would also identify them by other chracteristic non-facial features by way of "scanning" the whole person with his eyes from the feet upwards until he saw a familiar feature, e.g. his son's belt. Trying to look around the person by moving his head or asking him to turn, was another way of identifying the "Gestalt" piece by piece before he grasped it as a whole. This patient, who assertained that he definitely could see and knew the meaning of objects, would recognize and identify a cup, a pencil or a key only as he touched and handled them. By way of tactile identification he seemed to overcome a defect of countour and shape perception. Visual shape identification is supposed to occur over striate and peristriate zones, corresponding to a deficit in "aperceptive agnosia" [31]. This patient underwent an episode of severe hypotension during the course of ECC and later showed scintigraphic evidence of occipital lobe infarction as well as clinical signs of basal ganglia involvement–a moderate akinetic Parkinson syndrome.

Prosopagnosia is one of the most striking agnostic symptoms and demonstrates well the dissociation of seeing and perceiving, i.e. illustrates the gnostic aspect of vision. It may be conceived as a negative hallucination. The localization of prosopagnosia is uncertain; it has recently been described in two cases of recovery from cortical blindness–together with disturbances of colour recognition, incriminating the occipital lobe [6]. But there are cases known with involvement of the corpus callosum [26] and with lesions of the peripheral end organ [5].

There were three cases of *cortical blindness* which presented as *Anton's syndrome,* i.e. denial of blindness–as an expression of anosognosia–in organic brain disease. Two cases were reported at first by the staff as being hysterical. Psychogenic or hysterical blindness after cardiac surgery has been described before [18, 20], though these diagnoses were probably false. Cortical blindness, however, due to anoxia or embolization of the occipital lobe has been reported [4], and may also occur after cardiac arrest and myocardial infarction [33, 58].

The occipital poles are known to be the cortical area most affected by stagnant hypoxia; they are the terminal areas of vascular supply of the posterior and middle cerebral arteries. The failure of recognition of blindness is a common feature of hypoxic cortical blindness, though Anton's syndrome is not specific for this symptom, since it also occurs with bilateral optic nerve lesions. The only requirement seems to be a general reduction in cerebral function during any kind of blindness [61].

This general reduction of cerebral functioning is probably the main reason for other forms of *anosognosia*, or lack of awareness of disease. In our investigation there were four cases of *denial of cardiac surgery,* with these patients not realizing that the operation had already taken place. This gnostic defect was, however, not associated with visual symptoms. It appeared to be especially striking in the absence of other severe neurological symptoms or gross and obvious mental disturbances which could be detected at first sight. The large operation scar on the chest would not be recognized or accepted in connection with the heart operation; the patients had, in fact, no explanation for it. Galdstone (1970) reports of a delusion of having actually died after the operation [24].

Anosognosia has been described with respect to cortical blindness, hemiparesis, aphasic disorders [13], alexia, hemibalismus and deafness [62]. Denial of operation has been reported in patients after prefrontal lobotomy [22] and prefrontal lobectomy [49], though no cases have so far been reported following general or cardiac surgery. The discussion has centered around whether focal lesions can produce anosognosia or whether diffuse involvement of the brain is necessary. Anosognosia has been observed by Weinstein and Kahn in 22 cases of brain tumor [62]. The tumors were situated in various parts of the brain, including frontal, temporal and parietal lobes. According to the authors anosognosia never occurred as a single phenomenon. The complete syndrome showed spatial and temporal disorientation, disturbance in psychomotor activity, alteration in the use of language and in some cases hallucinations (hallucinations will be discussed in the next section). Our case presentations would support the thesis that diffuse involvement of the brain may also produce anosognosia in the absence of other focal neurological symptoms. A careful and detailed psychopathological examination showed however, that there were changes in affect and a severe alteration of the personality as a whole. This change of personality could also be detected in other patients with gnostic disorders beside anosognosia. Most, but not all of them, did not appear to be significantly disturbed by their symptoms, even if they were aware of them. Anosognosia in its extreme manifestation as total unawareness of disesase is best explained as a gross gnostic defect of high intellectual functioning with regard to full consciousness of oneself (a similar defect of ego-consciousness will be discussed under hallucinatory phenomena). It can only be understood fully in comparison or contrast to other severe cerebral lesions where patients are indeed aware of their defect and retain judgement and insight into their situation. These patients know that the operation was not successful and understand the implications of a cerebral accident and realize their fate. They are disturbed by their symptoms but with no mental detachement, neglect or even denial of the defects as in the typical group of patients with agnostic disorders.

2.3.2 The Hallucinatory Phenomena

Visual hallucinations were the most conspicious symptom of the second group of patients. They occurred as hallucinations of the "delirium type", not highly organized,—accompanied by mental confusion and disorientation—and as hallucinations of the "spectator type", which occurred without clouding of consciousness and without disorientation. They were of a highly organized type, representing complex sceneries.

2.3.2.1 Hallucinations of the Delirium Type. The delirium type of hallucinations were, as in general, of a frightening and threatening character, and since they occurred as a rule within a paranoid frame of thinking, they typically elicited fear and anxiety. Horror dreams and visual hallucinations of bodily mutilations were quite common. A very typical feature was the experience of being dissected alive. One patient experienced a form of *heautoskopia.* As he woke up after the operation, he saw his head dangling from the ceiling. He made sure that he was not dreaming as he observed his neighbours to his right and his left and he watched the nurses in the intensive care unit. Than he closed his eyes but continued to see his head dangling from the ceiling, once asleep he dreamt of his head, and when he awoke his head was still dangling from the ceiling.

The hallucinatory nature of dreams and their relationship to delusional ideas is well studied in certain types of cardiac psychoses. Following cardiac surgery one can indeed find all kinds and grades of the transition from dreaming to experiencing the dreams as hallucinations. A characteristic of many patients was that they slipped in and out of the hallucinary state or the state of dreaming with intervals of insight and lucidity—hence Jackson's term "mental diplopia" is appropriate. The accounts of the various experiences can be summarized as follows: (1) Most of the patients had dreams following cardiac surgery which *could be corrected at the moment of waking* or within a few seconds. They knew that they had dreamt. (2) Some patients stated that the *dreams as they woke up would continue as hallucinations,* and that they therefore could no longer distinguish between sleeping and being awake. Insight into the nonveridical nature of their dreams was no longer possible, because there was no point of reference around which critical judgement towards "inside" and "outside" a special state of consciousness could take place. (3) Some patients complained of repetitive vivid dreams or hallucinations *as soon as they closed their eyes* and they would therefore try to stay awake because of the fear, as expresssed by some, that the "film" would go on if they did not "control their mind". (4) Others insisted that they *dreamt with open eyes or "saw things"* in the sense of hallucinations, and that the visual phenomena disappeared as soon as they closed their eyes. They therefore lay in bed pretending to sleep in order not to watch these pictures.

These various phenomena show that different states of consciousness, with its particular function of reality testing, must have an influence on dreams and visual hallucinations. Etiological and pathogenetic factors will be subsequently discussed.

2.3.2.2 Hallucinations of the Spectator Type. The spectator type of hallucinations were—quite in contrast to the delirium type—not of a frightening character and

not typically accompanied by gross delusional ideas. The hallucinations themselves were quite characteristic, they represented complex scenes with great detail and centered on a major unchanging theme or story, e.g. two patients watched a soccer game, another a military parade, and another a carnival; people with masks or other carnival fancy dress were seen entering and leaving the recovery room. Another patient (a hunter) watched a safari scene in Africa and suddenly believed himself to be activily involved. He felt in the midst of antilopes and buffaloes and at one point he became frightened, because the pictures were so real that he believed himself to be in danger as a buffalo attacked him. He then actually asked the doctor to turn off the television. The metaphore of "watching a TV program" or "seing a film" was used quite often by these patients. They insisted however that the pictures were true and real and were not to be confused with dreams or illusions and occurring only when they were awake and with their eyes open. There was generally no direct affect of anxiety and fear connected with the hallucinations of the spectator type, however the high degree of reality of these scenes that the patients had together with the impression of taking part were sometimes frightening. This type of *reactive or induced fear of a secondary involvement* is quite different from the *psychotic fear of primary involvement,* which is characteristic of the delirium type of hallucinations. Because of the absence or lack of primary involvement in these hallucinatory phenomena the patients often wondered and marvelled rather than became disturbed and there was sometimes the affect of amazement and amusement as they watched the pictures. At times they were even emotionally detached from the hallucinations which reminded one of certain patients with gnostic disorders. The only disturbing element with these hallucinations was that they recurred again and again and that they could not be "turned off". They were not only seen on the ceiling or the wall, but also in stereoscopic fashion in the midst of a room. They could last from hours up to 10 days after the operation as was the case with one patient. Most patients would agree that the scences which they saw were hallucinations. As time went on insight into the deceptive nature of the pictures was sometimes undermined and could become partial and fluctuating. This is a good example in psychopathology, of how with length of time, the hallucinatory phenomena may finally be incorporated into the thought process of a person. Apparently the strength or ability of gnostic differentiation between "real" and "not-real" phenomena or "belonging" or "not-belonging" to one's concept of self or existantiality finally becomes weaker or disappears totally.

Though visual hallucinations may arise as a result of a disorder at any level of the visual passway, from the peripheral end organ to the area striata [61, 63], it is recognized clinically that structures of the *brain stem,* especially of the *diencephalon,* are of utmost importance in the etiology of visual hallucinations [50], thus supporting the evidence of a brain stem contribution to visual perception in man [59]. Highly organized visual hallucinations usually also indicate involvement of the temporal lobe [61]. Not only visual hallucinations but also metamorphopsia may occur in circumscribed lesions of the visual cortex [31].

The two major types of visual hallucinations, one of the delirium type and the other of the spectator type, also show that optical phenomena must have different localizations and associations in the visual pathways. It is also obvious that con-

sciousness and gnostic functions of reality testing play an important role. Visual hallucinations can be conceived in the context of our discussion as the extreme opposite of Gestalt-dissolution and related phenomena. In both cases gnostic functions are involved. On the one hand visual phenomena at the highest level of optical organisation appear in the external world as projections of reality—and on the other hand stability of the external world can no longer be maintained because of a lack in visual synthesis so that reality becomes not existant. We have also seen that transitions within different categories of phenomena and from one major category into the other may occur. In some instances it was quite impossible to differentiate between metamorphopsia and hallucinations. Or did the patients hallucinate metamorphic objects? Transitions within hallucinatory phenomena may develop from elementary unformed hallucinations as lines, spots, and geometrical figures to those of a pictorial nature and sceneries, from which the delirium type of hallucinations generally develops. On the other hand highly organized hallucinations may occur from the very beginning and may remain highly organized without changing or disintegrating.

The *role of psychological factors* in the origin of visual disturbances has not been discussed so far. It is known that there may indeed exist a great deal of overlapping or interaction of somatogenic and psychogenic causes when it comes to the question of etiology. This is true not only for the visual symptoms but also for psychological dysfunctions after cardiac surgery generally. In this connection the intensive care unit (I.C.U.) has often been thought to play an important role in the etiology of psychological disorders. In this case it could be argued that pathological changes in perception may also be caused by abnormal sensory input by optic (and acoustic) overstimulation or sensory deprivation of normal stimuli. Egerton and Kay [20] noted from patients remarks that visual hallucinations were originating from the monotony of the ceiling, and manifesting themselves initially as patterns on the ceiling or faces protruding from the small regular holes in the tiling. Such illusional misinterpretations of patterns are known to be characteristic of delirium generally. The role of psychogenic or non-primary organic causes for certain visual phenomena is not to be denied. Impairment of gnostic functions however seems to play a major role in the origin of such illusions. This also explains that patients in delirium are very suggestible. On the other hand the delirium type of hallucinations in cardiac surgery may illustrate that it is sometimes impossible to decide whether the pathogenesis of an hallucinatory symptom is primarily determined by a disturbance of consciousness, perception or affect. As any may predominate at any one time and influence the function of gnostic differentiation, the phenomena themselves seemed to change in character. Dreams, hallucinations, and illusions may occur at the same time, or so fast after each other, that they can no longer be differentiated. The critical point always seems to be the degree of impairment of reality testing, i.e. the involvement of gnostic functions. In the investigation of Heller et al. [32] patients with a "minor delir" had difficulties distinguishing between dreams and reality and those with a "major delir" showed frank hallucinatory episodes with paranoid elaborations. In the interpretation of these phenomena, as the authors stressed, some dismissed them as temporary aberrations attributable to narcotics, poor sleep or the stress of the operation, others thought they were "going crazy" or

were victims of a paranoid plot and some actually stated that they were suffering from a "recovery room delirium". Visual hallucinations may recur during sleep and are compared to visual phenomena characterizing night mares [57]. All these are cases of delirium with impairment of orientation and accompanied by some degree of mental confusion. In this investigation the majority of visual phenomena, except those of the delirium type, were not characterized by disorientation and gross mental confusion as is typical of delirium. Furthermore, the different hallucinations and phenomena like micropsia or macropsia could be observed not only during the time when the patients were in I.C.U., but also when they were moved into their individual rooms. It should also be remembered that following cardiac surgery the great majority of patients show no abnormal psychological reactions in I.C.U., nor do they have visual disturbances. The fact that I.C.U. does play a role in minor and major psychopathological syndromes depends not so much on the technical environment as such but on the various degrees of cerebral cortex impairment. This impairment may be only temporary and not very severe, but nevertheless it may produce a specific symptomatology. One phenomenon, not mentioned so far, was the intense experience of *after images* which only appeared in I.C.U. A doctor or a nurse would remain for a considerable time as an after image when they had left the bedside. These after images were sometimes so intense that the patients wondered whether they might be called real, but they could always be distinguished from hallucinations, because they vanished relatively quickly and there was always insight into their nature. Since *verbal perseveration* can be observed quite often after cardiac surgery, these after images could be understood as *visual perseverations*. However perseverations are generally an indication of an organic cerebral involvement, and are also very often only transient. From the point of psychopathology the enhancement of after images as well as hallucinations could be understood as an opposite phenomenon of the Gestalt-dissolution. Generally when the CNS is damaged globally, the sensory systems in man, and particularly the sensory visual system, is no longer able to cope with the disturbing elements of I.C.U. Sleep deprivation also plays an additional role. This explains why patients with CNS involvement who are exposed to the impersonal technical environment in the recovery room or I.C.U. especially feel the emotional deprivation of human touch and atmosphere. Others however, who are not in a critical somatic condition, even feel relieved at being in a "safe environment" as long as they are in I.C.U.

3 Causes

The growing literature on the subject of psychological disturbances following cardiac surgery today focusses on preoperative predictions of postoperative complications on the basis of somatic and personality factors, social environment and on man's relationship with a mechanical and frightening environment in the recovery room or I.C.U. Cardiac delirium and cardiogenic psychoses were however known long before cardiac surgery began, when rheumatic heart disease, endocarditis, and acute and chronic heart failure could not be treated as effectively as today. The exact study of an extensive literature on the subject

shows that there is *no difference in the psychopathological syndromes* of cardiac psychoses in the course of cardiac surgery and other cardiac diseases, including visual disturbances, gnostic disorders and hallucinatory phenomenon [27, 30, 34, 38, 42, 56]. There are two other systemic diseases which simulate the pathophysiological conditions of open heart surgery and produce identical neuropsychiatric syndromes, *polycythemia* and *malaria,* and psychoses and visual disturbances may accompany both [3, 14, 29, 44, 52]. The lesions of the brain in polycythemia vera and in cerebral malaria and in many patients dying following open heart surgery, especially with ECC, are the same: there is evidence of *embolic* and *anoxic changes.* Vascular occlusion and the slowing of the circulation play a role in polycythemia and cerebral malaria. Histopathological changes are those of anoxemia secondary to occlusion of small vessels [3]. The increased viscosity of the red cells in polycythemia and malaria does not always arrest the circulation but may cause a transitory state of ischemia [3]. Similar conditions may prevail in open heart surgery. In a retrospective investigation of 1360 non-selected patients [46] we found that there existed a significant correlation between use and duration of ECC (χ^2, $P<0.01$) and neuropsychiatric complications and also between specific priming of the machine, i.e. undiluted blood preserve or whole blood given during ECC (χ^2, $P<0.05$) and postoperative blood transfusion (χ^2, $P<0.01$) cf. [17].

Other significant (χ^2, $P<0.01$) correlations in detail were:

1. *Preoperatively:* (a) neuropsychiatric history, 42 (28.4%) of 148 patients with a previous neuropsychiatric history had cerebral disorders following cardiac surgery in comparison to 220 (18.2%) of 1212 patients without such a history, (b) advanced age over 40 years and extreme youth under 3 years, (c) low body weight below 10 kg in children and below 60 kg in adults, (d) acquired heart disease as opposed to congenital heart disease, (e) multivalvular lesions, (f) calcified lesions and (g) increase of NYHA functional class (the last one only χ^2, $P<0.05$).

2. *Intraoperatively:* (a use and b) duration of ECC, (c) duration of operation and (d) duration of hypothermia beyond 10 min (patients operated on without hypothermia showed cerebral disorders more often than those operated on with hypothermia of less than 10 min). Finally (e) rethoracothomies and (f) repeated defibrillation (the last one only χ^2, $P<0.05$).

3. *Postoperatively:* Besides (a) extensive blood transfusion, high levels of (b) urea, (c) potassium and (d) sodium (the last one only χ^2, $P<0.05$).

There are two areas of the brain where *specific vulnerability to microemboli and hypoxia* can be observed: the area of the occipital lobe [11, 12] and the basal ganglia [40, 51]. The role of the occipital lobe and the involvement of the basal ganglia in perceptual disorders as well as in the origin of hallucinations has already been discussed. There is evidence however that the brain stem structures also play a major role in catatonic and paranoid syndromes. This means that there are common anatomical structures involved in certain visual disorders and paranoid syndromes. A common psychophysiological basis for both seems to be a defect of gnostic function.

In the early days of cardiac surgery patients were described in the immediate postoperative period as being quiet, motionless and without facial expression, showing mask-like, frozen faces, resembling persons with a "catastrophic reaction" [2, 36, 43]. The open delusional psychotic syndromes developed later, between the 3rd and 5th postoperative day. In our own investigation we were able

to identify the patients of the early postoperative period as those with a mutistic and catatonic syndrome with a parkinsonian-like facial expression [40]. Many of them had at the same time visual disturbances as they would reveal later. There is clinical evidence that the states of mute alert appearing as immobility, as described in akinetic mutism, cannot really be distinguished from psychotic mutism in catatonic schizophrenia and in exogenic akinetic syndromes. Embolization and hypoxic changes of the basal ganglia and temporary disconnection of their neuroanatomical motor systems seem to provide a pathophysiological explanation for these reversible psychomotor disturbances following cardiac surgery [40, 48]. Paranoid delusions which appear between the 3rd and 5th postoperative day do play a role during this period of mutism, but are not detectable. These patients behave like mutistic, catatonic schizophrenics who describe, at a later stage of their disease, that they were unable to talk or move at the time of acute illness, and that they therefore could not reveal the delusional content of their thoughts. Reversible microembolization and/or transient hypoxic changes in the area of the basal ganglia seem to explain the phenomena of transient mutistic-akinetic syndromes. There is microanatomical evidence that occlusion of capillaries by microemboli of thrombocytes, leucocytes and of silicon, which occur in ECC, may be reversible [47]. This may also explain the different and transient psychopathological syndromes in cerebral malaria which are identical with those following open heart surgery and which were summarized by Arieti [3] as 1) acute delirium or confusional psychoses, 2) paranoid syndromes or delusional psychoses, 3) typical psychoses such as schizophrenia and manic-depressive psychoses and 4) organic conditions.

3.1 Summary and Conclusions

The 45 patients with visual disturbances following open heart surgery were investigated by analysing their visual experiences. They could be divided into disturbances of (1) visual acuity, (2) visual accuracy and (3) visual reality testing. Clinically one can distinguish between the non-hallucinatory and the hallucinatory phenomena. The most important of the first group were metamorphopsias, loss of colour vision, various gnostic disorders and cortical blindness. The hallucinatory phenomena can be divided into the delirium type of hallucinations with clouding of consciousness and the spectator type of hallucinations with a clear sensorium. The psychopathology of these disturbances is discussed in relation to cardiac delirium and psychosis.

The main causes for the visual symptomatology and for cardiac psychoses are seen in microembolization and/or ischemic hypoxia. The basal ganglia and the occipital lobe are discussed as areas of predelection for embolic and hypoxic changes in relation to perceptual disorders and psychosis. The same neuropsychiatric disorders which occur following open heart surgery have been observed in the "cardiogenic psychoses" other than from cardiac surgery, when rheumatic heart disease, endocarditis, and heart failure could not be treated effectively. Identical psychoses may also occur in cerebral malaria and polycythemia vera which show the same embolic and anoxic neuropathological changes of vascular occlusions as are seen in many patients who die following open heart surgery, especially with ECC.

References

1. Åberg T, Kihlgren M (1977) Cerebral protection during open-heart-surgery. Thorax 32: 525–533
2. Abram HS (1965) Adaption to open heart surgery: a psychiatric study of response to the threat of death. Am J Psychiatr 122: 659–668
3. Arieti (1946) Histopathologic changes in cerebral malaria and their relation to psychotic sequels. Arch Neurol Psychiatr 56: 79–104
4. Alfano JE, Fabritius RE, Garland MA (1957) Visual loss following mitral commissurotomy for mitral stenosis. Am J Ophthalmol 44: 213–216
5. Bay E (1950) Agnosie und Funktionswandel. Springer, Berlin Göttingen Heidelberg
6. Beck U, Aschayeri H, Keller H (1978) Prosopagnosie und Farberkennungsstörung bei Rückbildung von Rindenblindheit. Arch Psychiatr Nervenkr 225: 55–66
7. Blacher RS (1972) The hidden psychosis of open-heart surgery. J Am Med Assoc 222: 305–308
8. Blachly PH, Starr A (1964) Post-cardiotomy delirium. Am J Psychiatr 121: 371–375
9. Blakemore C (1979) Representation of reality in the perceptual world. In: Brain and Mind, Ciba Foundation Symposium 69 (new series). Excerpta Medica, Amsterdam Oxford New York
10. Bliss EL, Rumel WR, Branch CHH (1955) Psychiatric complications of mitral surgery. Arch Neurol Psychiatr 74: 249–252
11. Brierley JB (1963) Neuropathological findings in patients dying after open-heart surgery. Thorax 18: 291–304
12. Brierley JB (1967) Brain damage complicating open-heart surgery. Proc Roy Soc Med 60: 858–860
13. Brown JW (1972) Aphasia, apraxia and agnosia – Clinical and theoretical aspects. Charles C. Thomas, Springfield/Ill.
14. Büssow H (1944) Über Psychose bei Malaria. Allg Z Psychiatr 123: 235–272
15. Cairns H, Oldfield RC, Pennymacker JB, Whitteridge D (1941) Akinetic mutism with an epidermoid cyst of the 3rd ventricle. Brain 64: 273–290
16. Cairns H (1952) Disturbances of consciousness with lesions of the brain stem and diencephalon. Brain 75: 109–146
17. Cullen DJ, Ferrara LC (1975) Fine-screen filtration of pressurized whole blood, packed cells, and fresh-frozen erythrocytes. Anesthesiologie 43: 578–581
18. Danilowicz DA, Gabriel HP (1971) Postoperative reactions in children: "normal" and abnormal responses after cardiac surgery. Am J Psychiatr 128: 185–188
19. Dubin WR, Field HL, Gastfriend DR (1979) Postcardiotomy delirium: A critical review. J Thorac Cardiovasc Surg 77: 586–594
20. Egerton N, Kay JH (1964) Psychological disturbances associated with open heart surgery. Br J Psychiatr 110: 433–439
21. Fox HM, Rizzo ND, Gifford S (1954) Psychological observations of patients undergoing mitral surgery. Psychosomat Med 16: 186–208
22. Freeman W, Watts JW (1943) Prefrontal lobotomy: convalescent care and aid to rehabilitation. Am J Psychiatr 99: 798–806
23. Freyhan FA, Gianelli S Jr, O'Connell RA, Mayo JA (1971) Psychiatric complications following open heart surgery. Comprehens Psychiatr 12: 181–195
24. Galdston R (1970) Psychotic reactions to the success of cardiac valvotomy: a case report. Psychiatr Med 1: 367–373
25. Gilman S (1965) Cerebral disorders after open-heart operations. N Engl J Med 272: 489–498
26. Gloning J, Gloning K, Jellinger K, Quatember R (1970) A case of "prosopagnosia" with necropsy findings. Neuropsychologica 8: 199–204
27. Gordon AH, Cohen W (1938) The mental complications of heart disease. Can Med Assoc J 39: 517–522
28. Guidoin R, Laperche Y, Martin L, Awad J (1976) Disposable filters for microaggregate removal from extracorporal circulation. J Thor Cardiovas Surg 71: 502–516

29. Haber J (1952) Psychosis in Polycythemia vera. J Nerv Ment Dis 115 : 537–540
30. Head H (1901) Certain mental changes that accompany visceral disease. Brain 24 : 345–429
31. Hécaen H, Albert ML (1978) Human Neuropsychology. John Wiley & Sons, New York Chichester Brisbane Toronto
32. Heller SS, Frank KA, Malm JR, Bowman FO Jr, Harris PD, Charlton MH, Kornfeld DS (1970) Psychiatric complications of open-heart surgery. N Engl J Med 283 : 1015–1020
33. Howkins J, McLaughlin CR, Daniel P (1946) Neuronal damage from temporary cardiac arrest. Lancet 250 : 488–492
34. Hutchinson EC, Stock JPP (1963) Paroxysmal cerebral ischaemia in rheumatic heart disease. Lancet 2 : 653–656
35. John CA (1964) Hallucinations after cardiac surgery. Nurs Times 60 : 1347
36. Kimball CP (1972) The experience of open heart surgery. Arch Gen Psychiatr 27 : 57–63
37. Kovaliov VV (1970) Cited by Abram HS. The prosthetic man. Comprehens Psychiatr 11 : 475–481
38. Krinsky CM, Merrit HH (1938) Neurologic manifestations of subacute bacterial endocarditis. N Engl J Med 218 : 263–266
39. Meyendorf R (1976) Psychische und neurologische Störungen bei Herzoperationen. Fortschr Med 94 : 315–320
40. Meyendorf R (1976) Hirnembolie und Psychose. J Neurol 213 : 163–177
41. Meyendorf R (1977) Zur Frage psychischer und neurologischer Störungen bei Herzoperationen. Thoraxchirurgie 25 : 339–344
42. Meyendorf R (1979) Psychopathology in heart disease aside from cardiac surgery: A historical perspective of cardiac psychosis. Comprehens Psychiatr 20 : 326–331
43. Meyer BC, Blacher RS, Brown F (1961) A clinical study of psychiatric and psychological aspects of mitral surgery. Psychosom Med 23 : 194–218
44. Müller E (1910) Über psychische Störungen bei Polycythämie. Folia Heamatol (Leipzig) 9 : 233–241
45. Paech R (1979) Cerebrale Störungen als Komplikation von Herzoperationen. Dissertation, München
46. Paech P, Klinner W, Meyendorf R, Reichart B, Kreuzer E (1980) Incidence of psychiatric and neurological complications after cardiac surgery – retrospective versus prospective studies. Second International Symposium on psychopathological and neurological dysfunctions following open heart surgery. Milwaukee, Wisconsin
47. Patterson RH Jr, Twichell JB (1971) Disposable filter for microemboli. J Am Med Assoc 215 : 76–80
48. Penry JK, Cordell AR, Johnston FR, Netsky MG (1959) Experimental cerebral embolism with antifoam. Am J Thorac Cardiovasc Surg 37 : 342–351
49. Peyton WT, Haavik JE, Schiele BC (1949) Prefrontal lobectomy in schizophrenia. Arch Neurol Psychiatr 62 : 560–571
50. Reimer F (1970) Das Syndrom der optischen Halluzinose – Sammlung psychiatrischer und neurologischer Einzeldarstellungen. Georg Thieme, Stuttgart
51. Schwartz Ph (1972) Apoplectic lesions of the brain in adults. In: Vinken PJ, Bruyn GW (eds) Handbook of clinical neurology, Vol 11. North-Holland, Publ Comp. – American Elsevier Publ Co., Amsterdam New York, pp 578–659
52. Silverstein A, Gilbert H, Wassermann LR (1962) Neurologic complications of polycythemia. Ann Intern Med 57 : 909–916
53. Silverstein A, Krieger HP (1960) Neurologic complications of cardiac surgery. Transact Am Neurol Assoc 85 : 151–154
54. Skagseth E, Frøysaker T, Refsum SB (1974) Disposable filter for microemboli in cardiopulmonary bypass. J Cardiovas Surg 15 : 318–322
55. Stockard JJ, Blickford RG, Schauble JF (1973) Pressure dependent cerebral ischemia during cardiopulmonary bypass. Neurology 23 : 521–529
56. Swash M (1970) Transient visual obscurations in chronic rheumatic heart-disease. Lancet 2 : 323–326
57. Taylor FK (1979) Psychopathology. Its causes and symptoms. Quartermaine House Ltd., Sunbury-on-Thames, Middlesex, England

58. Towbin A (1955) Recurrent cerebral embolism. Arch Neurol Psychiatr 73 : 173–192
59. Trevarthen C (1979) The tasks of consciousness: how could the brain do them? In: Brain and Mind, Ciba Foundation Symposium 69 (new series), Excerpta Medica, Amsterdam Oxford New York
60. Tufo HM, Ostfeld AM, Shekelle R (1970) Cerebral nervous system dysfunction following open-heart surgery. J Am Med Assoc 212 : 1333–1340
61. Walsh FB, Hoyt WF (eds) (1969) Clinical neuro-ophthalmology, 3rd edn. Williams & Wilkins Co., Baltimore
62. Weinstein EA, Kahn RL (1950) The syndrome of anosognosia. Arch Neurol Psychiatr 64 : 772–790
63. White NJ (1980) Complex visual hallucinations in partial blindness due to eye disease. Br J Psychiatr 136 : 284–286

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