Managing sickle cell trait in aortic arch surgery performed under deep hypothermic circulatory arrest: a case report

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Background: Patients with sickle cell disease and sickle cell trait (SCT) are at high risk of sickling crisis when undergoing cardiac surgery. Maintenance of homeostasis and avoidance of sickling risk factors including hypothermia can mitigate this risk. However, in patients undergoing aortic arch surgery, hypothermic circulatory arrest is required and cannot be avoided. Exchange transfusion is recognised as a potential treatment option although evidence for this is limited. This unique case describes a patient with acute aortic syndrome and SCT undergoing exchange transfusion as part of emergency aortic surgery.

Case Description: A 52-year-old male with known SCT presented with left hemiplegia, left facial palsy and left hemianopia and underwent computed tomography imaging which confirmed the diagnosis of ischaemic stroke secondary to an occluded right carotid artery due to a dissection flap from a type A acute aortic dissection. Blood tests were taken pre-operatively but results were not received prior to the commencement of emergency surgery. Results subsequently revealed haemoglobin S (HbS) 35% and haemoglobin A (HbA) 53%. The extent of the dissection meant that the operation required the patient to be cooled to 18 ℃ with the associated risk of sickling crisis and microvascular obstruction. After multidisciplinary discussions with anaesthetic and haematology colleagues and also with other cardiac surgery centres, he underwent emergency surgery. At the beginning of cardiopulmonary bypass, a 50% exchange transfusion was performed, whereby 50% of the patient's blood was discarded. Simultaneously, the prime from the bypass machine (six units of sickle-negative blood) was transfused into the patient. Full bypass was then established. Mechanical aortic valve replacement and replacement of aortic root, ascending aorta and hemi-arch was then subsequently successfully performed under deep hypothermic circulatory arrest at 18 ℃ with selective antegrade cerebral perfusion delivered via the left carotid artery. He suffered no major post-operative complications.

Conclusions: Exchange transfusion at the start of bypass can be performed successfully to minimise the risk of sickling crisis during hypothermia for emergency aortic surgery.

Keywords: Cardiopulmonary bypass (CPB); sickle cell disease (SCD); deep hypothermic circulatory arrest (DHCA); aortic dissection; case report

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Introduction

Sickle cell disease (SCD) is an autosomal recessive disorder characterised by a replacement of the normal haemoglobin A (HbA) protein with a mutated haemoglobin S (HbS) protein. Patients with sickle cell trait (SCT) have a significant proportion of HbS (usually 30–45% of total blood volume) (1) and are frequently asymptomatic. They nevertheless remain susceptible to complications such as anaemia and thrombosis as a result of the disruption to red cell architecture associated with sickle cell dysfunction (2).

Complications due to sickling crisis are frequently precipitated by disturbances to homeostasis such as hypothermia, acidosis, hypoxia, dehydration, stress, inflammation and infection. Most of these factors are present during aortic surgery and are also associated with long cardiopulmonary bypass (CPB) time. Hence patients with SCT are considered high risk for cardiac surgery. Strategies to minimise risk include maintaining normothermia on CPB or avoiding CPB altogether. Other CPB considerations include the type of pump used (centrifugal *vs* roller), utilising CPB flows to achieve target blood pressure and minimising the usage of vasoconstrictors and also the prevention of acidosis with adjuncts such as administration of bicarbonate and performing renal filtration on CPB. In the elective setting, all of these factors can be comprehensively considered and optimised during the pre-operative work-up.

However, aortic arch/aortic dissection surgery requires moderate (MHCA) or deep (DHCA) hypothermic circulatory arrest for cerebral protection. For surgery where DHCA is needed, cooling is unavoidable, and so to minimise the risk of sickling crisis, in an elective setting pre-operative exchange transfusion can be performed to reduce the proportion of HbS in the blood (3). Exchange transfusion is now an accepted and well-established treatment for patients with sickle cell pathology for treatment of sickling crisis (4).

However, the lack of consensus and guidelines as to how to manage these patients remains a problem. The magnitude of the problem is heightened in the context of emergency surgery, when appropriate pre-operative optimisation is lacking and time to discuss the complexities of the case with colleagues in other centres across the world is impractical.

This case report describes a scenario where a patient required emergency surgery for acute type A aortic dissection. Exchange transfusion was performed safely and expeditiously in theatre at the beginning of cardiopulmonary bypass, to prevent sickling crisis. We present this case in accordance with the CARE reporting checklist (available at https://amj.amegroups.com/article/view/10.21037/amj-23-94/rc).

Highlight box

Key findings

- Exchange transfusion can be safely performed to minimise sickle cell crisis in patients undergoing emergency cardiac surgery where hypothermic circulatory arrest is unavoidable.

What is known and what is new?

- There are few published cases describing adult patients with sickle cell pathology undergoing cardiac surgery. This case modifies an existing approach to exchange transfusion immediately prior to institution of cardiopulmonary bypass in a patient undergoing emergency surgery for acute aortic syndrome necessitating hypothermic circulatory arrest.

What is the implication, and what should change now?

- Elective patients at high risk of sickle cell pathology should be routinely screened. In the emergency setting, exchange transfusion can be safely performed to minimise the risk of sickle cell crisis.

Case presentation

A 52-year-old Caucasian male presented to a District General Hospital with left-sided hemiplegia, left facial palsy and left hemianopia. Imaging in the form of a carotid duplex scan and computed tomography (CT) of the head demonstrated a right temporoparietal infarct secondary to an occluded right carotid artery. He became more unwell over the next 4 days and subsequently underwent a CT scan of the thorax and abdomen on day 4 after admission. This demonstrated the presence of a type A acute aortic dissection extending from the aortic root into the aortic arch and also into the innominate artery with a dissection flap occluding the right carotid artery. A transthoracic echocardiogram demonstrated moderate to severe aortic regurgitation and moderate left ventricular systolic dysfunction. He was referred to our service on day 5 and was immediately transferred to our tertiary centre for emergency surgery.

He was a current smoker of tobacco and cannabis and had evidence of emphysema on his CT scan. He was also known to have SCT, which was diagnosed incidentally in childhood after he suffered excessive bleeding during a dental extraction. He had never had any sickling crisis and

was otherwise asymptomatic. The proportion of HbS was unknown and blood samples were taken pre-operatively for confirmation, but due to the time-sensitive nature of acute type A aortic dissection, emergency surgery was required prior to the results being received. His platelet function test [performed using Multiplate® technology (Roche)] showed approximately 40% platelet function and therefore several units of platelets were ordered pre-operatively as a precaution. Neurologically, despite an established left-sided dense hemiplegia for 5 days, he remained fully conscious and with a Glasgow Coma Score of 15/15.

After multidisciplinary discussions with anaesthetic and haematology colleagues and also with surgeons and perfusionists in other cardiac surgery centres, exchange transfusion of 50% of the calculated circulating blood volume was planned. The alternative strategy of performing the operation without performing an exchange transfusion was considered. However, the risks of this approach were felt to be higher than any risks associated with exchange transfusion, particularly given that the HbS and HbA percentages were not known at this time. Therefore, 12 units of specifically requested "sickle-negative blood" was cross-matched (6 for the exchange transfusion and 6 for surgery) and he was transferred to the operating theatre for emergency cardiac surgery. This discussion, appropriate consent and operative planning took place immediately upon arrival in our centre.

Normothermia was maintained in the anaesthetic room with a warming blanket and warmed intravenous fluids. Anaesthesia was induced using midazolam, alfentanil and rocuronium, and was maintained using isoflurane and an infusion of alfentanil. Strict avoidance of hypoxia was observed throughout the case. After administration of heparin and placement of lines for CPB, a 50% exchange transfusion was performed using the bypass machine, before CPB was established. The exchange transfusion process was undertaken after adaptation from a protocol received from another cardiothoracic surgical centre in the UK utilised for other types of surgeries. His body mass index was 21.6 kg/m^2 and his starting haemoglobin level was 120 g/L. The bypass machine had been primed with six units of sickle-negative blood. His circulating blood volume was calculated at 4.4 L and the target was to remove 50% of this. As 2.2 L of blood from the patient was drained via the venous cannula, the sidearm of the venous pipe was connected to a suction bottle and discarded. Simultaneously, the same amount of sickle-negative prime was transfused into the patient via the arterial cannula at the same flow rates as the venous drainage, so as to maintain blood pressure. The use of bypass cannulae and pipes made it possible to complete the exchange transfusion in less than one minute and thus avoid recirculation.

Once the desired amount of exchange transfusion was completed, full CPB was established, and cooling started. The shed sickle-positive blood from the surgical field was discarded. Although some studies have shown that intra-operative cell salvage can be used in patients with sickle cell pathology, we opted not to use it in this case. It was felt that the patient's shed blood red blood cells were likely to be sickled due to multiple factors including coming in contact with extravascular surfaces, and mixing with fat globules and diathermy smoke. Stasis in the cell saver reservoir in an acidotic, uncontrolled room temperature (i.e., colder than body temperature) environment was also a concern. Finally, cell-washing apparatus uses room temperature fluids, raising similar concerns. Therefore, it was deemed safer to discard shed blood and replace blood loss with donor confirmed sickle negative blood as part of the exchange transfusion process.

The patient was then cooled to 18 ℃ to facilitate mechanical aortic valve replacement, aortic root, ascending aorta and hemi-arch replacement, which was performed uneventfully. The CPB and cross-clamp times were 314 and 233 minutes, respectively. Circulatory arrest lasted for 28 minutes, with antegrade cerebral perfusion (ACP) delivered for 24 of those 28 minutes. We recognise that some centres use MHCA rather than DHCA, and rely on ACP for brain protection. All surgeons in our centre use DHCA, because inspection of the arch for any intimal tears and potential need for total arch replacement is routine in our centre. It can be particularly difficult to deliver ACP when the dissection flap in the arch extends into the carotid arteries, as was the case with this patient, where the right carotid artery was occluded by dissection flap. Whilst ACP is a luxury in a DHCA scenario, in the context of MHCA it is much more of a necessity. Therefore, given the already complex and rarely encountered aspects of this case, and as our ability to deliver ACP couldn't be assured, it was felt that adopting an MHCA strategy would be imprudent. The alpha-stat approach for blood gas interpretation was used throughout CPB.

Additional standard peri-operative monitoring included 5-lead electrocardiogram, pulse oximetry, invasive arterial pressure monitoring (radial and femoral), central venous pressure and cerebral oximetry (near infra-red spectroscopy). In the immediate post-bypass period we

utilised thromboelastogram measurements to guide the correction of any coagulopathies. The patient suffered no major post-operative complications, including no major bleeding or thrombosis. However, he did have evidence of non-occlusive thrombus in the neck veins seen on ultrasound. He was successfully discharged back to his stroke rehabilitation unit on the 23rd post-operative day. Blood results which came later confirmed SCT with HbS 35% and HbA 53%. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration (as revised in 2013). Written informed consent for publication of this case report was not obtained from the patient or the relatives after all possible attempts were made.

Discussion

Published case series of patients undergoing any form of cardiac surgery in the presence of concomitant sickle cell pathology are uncommon and therefore there is little consensus as to the preferred protective strategy (5). Moreover, the incidence of sickle cell crisis in patients with sickle cell pathology undergoing surgery involving DHCA is unknown, due to the limited number of published series in this select group of patients. Additionally, the majority of published literature on this topic is focussed on paediatric patients undergoing surgery for congenital heart disease. It remains unclear how the reported experience from these series can translate to adult patients with acquired cardiac pathology. However, there is evidence to suggest that patients with heterozygous SCT are less likely to experience peri-operative sickle cell crisis in comparison to their counterparts with homozygous SCD due to a lesser amount of circulating HbS (6). Yet, the avoidance of vascular and renal complications after cardiac surgery in these patients is primarily achieved by avoiding the factors, such as hypothermia, which precipitate crisis (7). Unfortunately, such a strategy cannot be implemented in the context of surgery on the distal ascending aorta and aortic arch, where DHCA is required.

Since the mid-1970s, DHCA has remained the mainstay of cerebral protection during complex surgical procedures. With the addition of adjuncts such as topical cooling, administration of steroids or barbiturates and direct antegrade or retrograde cerebral perfusion, cessation of systemic circulation can be tolerated for 30–60 minutes to facilitate completion of the surgical procedure (8). Despite these benefits, the process of cooling and rewarming can only be undertaken slowly and hence DHCA necessitates a prolonged period of CPB and its accompanying complications including acid-base disturbance, coagulopathy and microemboli. The need for hypothermia in the context of aortic arch surgery is however unavoidable and hence the peri-operative strategy must include a focus on reducing the proportion of erythrocytes within the circulating volume prior to cooling. As mentioned above, our reasoning for utilising DHCA and not MHCA was our concerns about being unable to deliver ACP given the occluded carotid artery as well as our unfamiliarity with MHCA in an already complex environment.

Whilst occasional studies have demonstrated that hypothermia during cardiac surgery does not significantly increase the risk of sickle cell crisis (3), our decision to perform exchange transfusion was underpinned by the fact that aortic arch surgery involves a prolonged period of profound hypothermia. The lack of published data in this specific group of patients directed us to utilise exchange transfusion to mitigate the essentially unknown but predictable risk of peri-operative sickle cell crisis. Whilst there is insufficient evidence in the literature to determine whether exchange transfusion truly lowers the risk of sickle cell crisis in this context, a similar approach of exchange transfusion was employed by a team from another hospital in the UK as part of their strategy to reduce the risk of sickling crisis in patients with SCT undergoing other surgeries, which also involve DHCA (9).

Exchange transfusion is a well-established strategy employed to reduce the risk of and treat sickle cell crisis, although no randomised trials underpin this practice. Nevertheless, guidelines advocate the use of exchange transfusion to achieve an HbS level <30% in high-risk situations, which includes cardiac surgery (10). It is particularly relevant in the context of DHCA, when the risk of sickling is so much higher. Priming the bypass circuit with sickle-negative blood allows the patient's sickled blood to be simultaneously replaced before CPB is established and hence the procedure can usually be undertaken without inducing haemodynamic instability. Such a strategy was employed in this case, which subsequently passed without sickle cell crisis or any other major complications.

The caveat is that many patients with SCT have never been formally diagnosed, given its frequently asymptomatic nature. We were fortunate in this case as the patient was conscious and was able to provide us with his full medical history. The prevalence of SCT is often under-estimated

in the western world and selective testing based on ethnic origin is not reliable with mixing of gene pools. In the UK, it is estimated that 1 in 78 new-born babies carry the gene for SCT, although for people of African ancestry or who identify as black, the figure is substantially higher (11).

Conclusions

A first presentation with intra-operative sickle cell crisis during a period of DHCA would be catastrophic and centres who regularly carry out aortic surgery under DHCA could consider screening for the presence of HbS in all patients undergoing elective aortic surgery under hypothermia either routinely or selectively for patients deemed to be at higher risk of carrying the gene for SCT (i.e., those whose ethnicity or ancestry is recognised as higher risk). For those found to have a high HbS proportion, the exact percentage should be considered in order to plan exchange transfusion, which can be performed expeditiously and safely in theatre, before CPB is commenced. In an emergency situation with a type A dissection, as described in this case, we believe that the most prudent approach would be to perform exchange transfusion to minimise the risk of sickling crisis complications, amidst an already complex and high-risk operation.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at https://amj.amegroups.com/article/view/10.21037/amj-23-94/rc

Peer Review File: Available at https://amj.amegroups.com/article/view/10.21037/amj-23-94/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://amj.amegroups.com/article/view/10.21037/amj-23-94/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration (as revised in 2013). Written informed consent for publication of this case report was not obtained from the patient or the relatives after all possible attempts were made.

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