

Indian Journal of Extra Corporeal Technology

Official Journal

Indian Society of Extra Corporeal Technology

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Vision, Mission and Guidelines for authors

The Indian Journal of Extra-Corporeal Technology (IJECT) invites manuscripts from all perfusionists and related healthcare professionals, interested in highlighting practices relevant to extra-corporeal circulation. Manuscripts highlighting protocol, innovations and review of current practices, aimed at improving the standards of safe, scientific conduct of the science of extra-corporeal circulation are earnestly solicited for publishing in the journal.

Vision:

The Journal aims to highlight the scientific achievements of the perfusion fraternity of India in particular, accross the global forum. The Journal also aims to be a source of reference for guiding perfusionists in their continuous quest for improving clinical standards of practice.

Mission:

The Journal encourages the perfusionist community of India to project the innovations in perfusion currently being practiced, in line with internationally accepted guidelines of patient safety and care. The Journal also encourages other members of the cardiac surgical fraternity to provide clinical insights significantly influencing the practice of extracorporeal circulation. The Journal also provides a forum for emerging perfusionists to expand their knowledge and subsequently improve their skill sets during the conduct of extracorporeal circulation.

Indexing: Presently we are indexed in www.indianjournals.com

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- 1. **Original article:** Minimumword limit 5000 (excludingreferences), 40 references maximum, not more than 10tables/figures
- 2. **Mini review article:** Minimum word limit 2500 (excludingreferences), 20 references maximum, not more than 5tables/figures
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Manuscript must be in Arial font in .doc or .rtf only.Layout in single column and double space and 12 pointArial font . Charts may be patterned in black& white. Pictures should be 300 dpi JPEG or TIFF. Legends to figures with picture number, illustrations andphotographs etc. should be neatly given in a separatesheet. Submission of articles The manuscript should be submitted to the following E-mail ID pkumarpillai76@gmail.com

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Acknowledgements: of personal assistance should, if appropriate, be placed at the end of the text.

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Should always be relevant: more is notnecessarily better. They should be numbered in the order in which they appear in the text, and should be given in the 'Vancouver style'. Journals should be indexed and their abbreviations confirm to, Index Medicus.

References format should be as follows:

Journal author(s), title of the article, name of the journal, volume number, page numbers (inclusive). Book—author(s) title of the book, place of publication, publisher, year, page number used.

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From the Editor's Desk



"Lead us from darkness in to light"

- Brihadaranyaka Upanishad

This English Translation of an ancient Indian Verse sums up the importance of acquiring knowledge. Knowledge is the only catalyst that can transform the darkness of ignorance in to the light of realization. Hence acquiring knowledge should be the sole concern of an individual. Equally important is the right use of the knowledge acquired. Knowledge put into action is similar to water released from a dam, capable of generating power and positively transforming lives.

On this note I start my journey as the new Editor-In-Chief of the Indian Journal of Extra-Corporeal Technology (IJECT). I would like to extend my sincere gratitude, to the previous incumbent of this illustrious position and the team members who gave their immense contribution to develop this journal as it stands today.

In the same breath, I also wish to extend a warm welcome to all members of the new Editorial Team and sincerely hope to fulfill all the expectations of providing a responsible sounding board whilst highlighting the scientific achievements of the Indian Society of Extra-Corporeal Technology, in front of the global community.

I sincerely exhort all perfusionists to utilize the journal and highlight the innovations being created in clinical practice as well as interesting case reports which will further enrich the ever expanding treasure trove of scientific data.

I also request other healthcare and scientific professionals to contribute relevant information from their practice which could enhance and significantly contribute to improving practice guidelines of Extra-Corporeal Circulation.

With best regards Sincerely **Pradeepkumar Chandrashekhar Pillai** E-mail: pkumarpillai76@gmail.com Indian Journal of Extra Corporeal Technology



Message from President, ISECT



Dear Esteemed Members of the Perfusion Fraternity,

It gives me immense pleasure in introducing the Indian Journal of Extra-Corporeal Technology (IJECT), the official journal of the Indian Society of Extra-Corporeal Technology (ISECT).

The journal highlights the clinical achievements of perfusionists in India. The journal provides a responsible foundation for inculcating scientific temperprojecting innovative practices as well as challenging, interesting case reports somewhat unique to the practice of clinical perfusion in India and yet, in compliance with international guidelines of evidence based practice.

I hereby take this opportunity to convey my best wishes to the Editor, Mr. Pradeepkumar Pillai and entire Editorial Team of IJECT. I invite all the perfusionists as well as other healthcare professionals to utilize the journal and contribute their clinical experience, which will certainly go a long way in supporting the ever continuing quest of professional excellence as well as refining standards of the practice of clinical perfusion.

Thanking You With regards **Simon Richard Pinto** The President of ISECT (Indian Society of Extra-Corporeal Technology.)



Message from President, IACTS



Dear friends,

It gives me great pleasure to appreciate and acknowledge the immense contribution our Perfusionists have made towards the growth of Cardiac surgery in India. The clinical innovations in perfusion strategies employed by our perfusionists, for challenging surgical procedures, reflect the rich academic insight, clinical expertise and scientific temperament of the entire Perfusion community.

This vast plethora of information has to be documented and presented before international fora ,as it could contribute to updation of practice guidelines, thereby significantly improving the standards of patient care and outcomes.

The Indian Journal of Extra-Corporeal Technology (IJECT) provides a strong platform for highlighting the achievements of the Perfusion community of India. I strongly urge as well as encourage more participation of Perfusionists by contributing scientific articles, which will in, due course significantly contribute to peer recognition as well as professional growth.

I sincerely extend my best wishes to the Indian Journal of Extra-Corporeal Technology (IJECT) and to its Editorial Team. I also extend all possible support and encouragement from the Indian Association of Cardiovascular and Thoracic Surgeons (IACTS) to make the journal an illuminating and enriching medium of information regarding clinical perfusion services.

Wishing you all great success in all your activities.

With Best Wishes Dr. Shiv K Nair, MBBS, MS(PGI), MCh, FIACS, SLP(Harvard) President, Indian Association of Cardiovascular and Thoracic Surgeons Indian Journal of Extra Corporeal Technology



From the General Secretary's Desk



It gives me immense pleasure to see the release of the new edition of the Indian Journal of Extra Corporeal Technology (IJECT) under the new editor Mr.Pradeepkumar Pillai and his team of editorial board members. A new team always brings in fresh ideas and gives the youngsters a chance to prove their talent in various other roles apart from practicing perfusion. It also serves as a role model for the young aspiring perfusionist to take up these roles in future and raise the standards of Perfusion technology.

In order to save cost and be more environmental friendly the new team has decided to print limited copies of our IJECT Journals and circulate the rest as E-copy which will be available in the email and mobile phone and you can read it on the go. We sincerely hope that the General Body will also agree to this initiative and give the green signal for the team. The new team has also come out with new ideas like interview with the surgeons, guest articles from Cardiac Surgery and Anaesthesia, apart from scientific articles from our own Perfusion Fraternity.

The Indian Perfusionists are very innovative in their techniques and bring in lot of fresh ideas working in a resource constrained environment unlike the west. But where we lag behind is in data collection, correlation of the data and presenting scientific papers. In spite of having wide variety of cases our perfusion community comes out with abysmally less number of scientific papers compared to the west. We need to focus on learning little bit of research methodology, basic medical statistics and terminologies to overcome this. I am sure the future generation of perfusionists will overcome this and it is our dream to surpass the west in terms of the number of meaning full papers which will bring in revolutionary changes in perfusion practices. It is a but a matter of time before we achieve this.

I congratulate our new editor Mr.Pradeepkumar Pillai and his team members for bringing out the fresh edition of IJECT and look forward for many more publications in the coming years. I also express my sincere thanks to our President Mr.Simon Pinto and his team of executive committee members for their leadership and constant source of encouragement.I also thank all the members of ISECT who contributed to this edition in terms of articles, suggestions and inspiration.

With warm regards,

P.V.S. Prakash General Secretary, ISECT



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Interview with Dr. Shiv K Nair, MS, MCh - President, IACTS

"Always Consider yourselves to be part of the team. The Perfusionist was, is and will continue to be an integral part of Cardiac Surgery" – This statement forms the crux of an interview with the President of the Indian Association of Cardiovascular and Thoracic Surgeons (IACTS), Dr. Shiv K Nair.

Presently ,as HOD, CVTS in Rajagiri Hospital, Aluva, Kerala, India, Dr. Nair took time off his busy schedule for an interview with the Editor-in-Chief, Indian Journal of Extra-Corporeal Technology (IJECT). The interview highlights the present scenario of perfusion training, scope of career and presents solutions to issues plaguing the fraternity, with an emphatic exhortation to perfusionists for proactive participation in research as well as documentation.

About Dr. Shiv K Nair:

Dr. Shiv K Nair is the Head of the Department and Senior Consultant of the Department of Cardiovascular & Thoracic Surgery at Rajagiri Hospital since November 2014. Prior to his appointment at this hospital, he was the Professor and Head of the Department of Cardiovascular Surgery at the Amrita Institute of Medical Sciences, a University Teaching Hospital (1999–2014). He began his career in Cardiovascular surgery as a Lecturer at the Seth G.S. Medical College and King Edward Memorial Hospital, Bombay in 1989. Subsequently he moved to Sree Chitra Tirunal Institute for Medical Sciences and Technology in Trivandrum as the Assistant and then Associate Professor [1990–1999].

Dr. Shiv K Nair has served as a Member of many National Committees namely, the National AIDS Committee and the Advisory Committee on Ph.D Thesis/Infection Control/Blood bank

With a teaching experience spanning more than 25 years, Dr. Shiv K Nair has also been a mentor to more than 50 cardiac surgeons, many of them who are presently heading cardiac surgical units across the country.

Among his chief interests in cardiac surgery include – Coronary Artery Bypass Surgery (Off Pump), Surgery for Heart Failure (LV reconstruction) ,Mechanical Circulatory Support (MCS), Surgery for Valvular Heart Diseases, Minimally Invasive Cardiac Surgery and Aortic Surgery.

1 Has the role of the perfusionist undergone an evolution with the advent of beating heart surgery, especially Off pump CABG?

Answer: The role of the perfusionist has definitely undergone an evolution, however the significance of the perfusionist has not diminished. The perfusionist is an integral part of the cardiac surgical team, more so in the settings of beating heart surgery wherein we need the perfusionist; there could arise a need to perform the procedure utilizing the heart lung machine. Perfusionists in the era of the beating heart surgery have evolved to co-ordinate the use of consumables and specialized equipment absolutely essential for safe conduct of beating heart procedures, even while preserving their core area of speciality. The role may have undergone some changes but the importance of the perfusionist has never diminished. Perfusionists have and will continue to be integral to the cardiac surgical team.

2 The number of institutions carrying out perfusion training is increasing with the number of perfusionists passing out every year creating huge disparities with respect to employment opportunities. What can be done to regulate this situation?

Answer: This is a major problem and needs to be tackled at the earliest to prevent things spiraling out of control. The Indian Society of Extra-Corporeal Technology needs to take up this matter with the authorities in a proactive manner. It is extremely unfortunate to see many perfusion students enrolling in training programs, often paying exhorbitant fees, only to graduate and see a job market with limited opportunities (due to large numbers of perfusionists graduating every year) and often ending up getting employed at sub-optimal pay packages, which lead to many of them getting ensnared in financial liabilities.



The office bearers of ISECT will have to come out with strict gudelines regulating the perfusion training programs across India, with regards to intake of students based on current and future employment requirements, etc. The Indian Association of Cardio-Thoracic Surgeons will always be supportive of any measures and suggestions given by ISECT to remedy this malady as well as set a corrective course of action.

3 Do you think that regulating the intake of perfusionists for training ,be on a certain ratio based on the total number of surgeons being trained for a career in cardiac surgery? Just as a perfusionist steps in to the OR for his training, a surgeon who has finished Post Graduation in Surgery enters cardiothoracic surgery for further superspeciality training. Based on this would you recommend a ratio (1 cardiothoracic surgeon candidate: 1 student perfusionist or similar ratios) as an ad interim step to control this influx of perfusionists?

Answer: I think that this is certainly one tangible step which can be considered for regulating the perfusion training across the country. However before implementing this step we should consider certain factors – the expected growth in percentage of cardiac surgical units annually, the percentage of increase in surgical procedures carried out in existing cardiac surgical units and the redundancy factor – there will be many amongst the perfusionists who opt out of the field due to retirement or alternative career routes, similarly to what happens amongst surgeons as well. Market factors predict a growth in cardiac surgery by almost 15 to 20%, which has to be considered for implementing long term strategies in designing and developing infrastructure as well as manpower. The Indian Society of Extracorporeal Technology needs to gauge present and futuristic market trends, keeping these factors in mind and design recommendations to the healthcare regulatory authorities as to regulation of perfusion training programmes in India.

It is important for ISECT to highlight an active membership database before meaningful decisions can be made.

4 As part of the on-going proceedings in the Allied Healthcare Bill which is being introduced in Parliament, office bearers had met with the Honorable Health Minister, Govt of India and members of the Board drafting the bill with the recommendation to augment the status of perfusionists in the Bill . Further steps would include to issue notices to institutions conducting perfusion training programmes across the country to review and regulate the intake of candidates for perfusion training. What in your opinion can be done further in this regards?

Answer: The office bearers of ISECT should expend the clinical importance of perfusionists to the bureaucrats in charge of drafting the Allied Healthcare Bill. The clinical significance of the perfusionist in cardiac surgery, the expansion of clinical perfusion services in diverse aspects of therapy, all of these have to be explained in detail to identify and give the perfusionists their duly deserved position amongst the allied healthcare professionals in the country. As said earlier once this is accomplished, then the task of regulating perfusion education should be initiated as per the recommendations of ISECT. The IACTS office bearers have and will always continue to support any initiative to improve the status of perfusionists.

5 With the advances in technology involving perfusion, there certainly is a need to evolve continuous training to keep abreast of latest technological developments. Which areas in your opinion do we, as perfsionists need to keep our training focused ?

Answer: The answer to this question is multi-layered; at the onset a solid, skill set evolution based training programs should be created for perfusion training. It is most unfortunate that many institutions conduct perfusion training programs at places where there is no cardiac surgery taking place. This practice has to be stopped. Secondly, all perfusionists who graduate out of their training programmes have to undergo a compulsory period of internship similar to medical graduates. It simply cannot be accepted that a rookie professional be given such a huge responsibility independently especially when a human life is at stake. The fresh graduates should be exposed gradually to the rigors of their professional career in a graded manner and under the watchful eyes of senior professionals who will mentor them and mould their career for greater responsibilities ahead. I would even suggest that such internships be held only in high volume and presitigious institutions as these institutions, by virtue of numbers can significantly contribute to the clinical



experience gained by the fresh perfusion graduate. Finally with the advent of new and emerging technology especially in the field of mechanical circulatory support, the perfusionists need to undergo continuous and graded training programs in such areas. In my opinion just like cardiac surgeons, perfusionists also need to evolve their training in line with changes in techniques/technology with a significant co-operation from the industry as they continue introducing new devices and systems for clinical use.

6 In countries like the US, UK and the European countries as well as in GCC countries, perfusionists are awarded clinical licenses to practice. In your opinion, will the implementation of such practice help in streamlining the perfusion fraternity in the country? If so, how can such a system be implemented? How can the cardiac surgical community help in this process?

Answer: This is one of the strategies that can be implemented in streamlining the perfusionist fraternity. The issue of professional license to practice, removes the heterogeneity so prevalent currently in the perfusion training programs. It is obvious that a perfusionist trained in a high volume prestigious training programme will have greater exposure than a perfusionist graduating from another institution that does not undertake comparative volume and quality of work. It will help weed out fraudulent organizations and streamline the professional caliber of perfusionists. Just like medical graduates, perfusionists also should have a clinical practice license. The creation of the Allied Health Council will pave the way for implementation of this process in due course. As regards the support of the cardiac surgical community in this endeavour, any process that brings about uniformity and improves the quality of practice is and should be welcomed. The Community of Cardiac Surgeons stands together with the fraternity of perfusionists rendering all possible support for any issue that is of concern to them. At present IACTS is conducting a certification Examination for perfusionists; it is a step in the right direction and can be further improved by mutual discussion.

7 Coming to another aspect, research is also an important aspect of professional growth more so in the era of evidence based practice. In your opinion what are the areas of research that are available for perfusionists in India? So also, will the current infrastructure of cardiac surgery in the country support such research?

Answer: Most of the perfusionists that I have had the good fortune of working with in my career are extremely innovative. I must and I say evocatively that our Indian perfusionists are very imaginative and produce innovations in their strategies according to the need of the surgical plan with whatever resources available. It is just that these innovations often go unnoticed and often undocumented. This trend has to be reversed. All innovative practices in the field of perfusion should be documented, subject to clinical scrutiny vis-à-vis evidence based practices and published. I personally recall an article published regarding the use of Del Nido Cardioplegia in Adult Cardiac Surgery, which was published from our institution in the journal **Perfusion.** Most of the background work regarding the documentation of data was done by our perfusionists, who are also among the authors of the article. This paper was the most read paper in the year 2015 or 2016 ; a feedback regarding the same was sent by the editorial board of **Perfusion** to our team. To summarise, any innovative practice (it need not be high end research) must be documented, clinically scrutinized and published. **The Indian Journal of Extra-Corporeal Technology** is an excellent platform for publishing such data. I strongly encourage perfusionists across India to use this platform as well as the Perfusion National Conference to highlight their clinical achievements, thereby gaining professional recognition of their contribution towards the growth of the fraternity.

8 Despite India being in the forefront of cardiac surgery, research publications related to perfusion has not been very forthcoming. In your opinion, what are the reasons for this? So also how can this "writer's block" be overcome?

Answer: This "writer's block" does not exist only for the perfusionists; it also exists for the surgeons as well. There are many reasons for this. Primarily the concept of "being too busy to write" is prevalent amongst our cardiac surgical



community. I do accept that most cardiac surgical units are running a heavy operating schedule but if we have time for our daily activities, we certainly do have time to write. It is all about prioritizing our schedules with making some time for academic and research work. The surgeons have started doing more work in publishing articles with more articles from India being published in cardiac surgical journals both here and overseas. It is time for the perfusionists to follow suit. To put it bluntly – The "writer's block" can only be overcome by writing.

9 Re-training, especially with high end state of the art equipment, is one of the requirements for keeping the professional edge. Unfortunately access to high end equipment is not as easy in India as compared to other countries. How can this challenge be overcome such that the professional edge is retained and updation of clinical experience remains a continuous process?

Answer: This issue needs to be looked from another angle; professional retraining is an extremely important factor in the career graph of every individual. However in India one cannot expect high end equipment like the Heartmate 3 to be used for every individual requiring Ventricular Assist Devices. An alternative to this, is the data emerging from increasing heart transplantation programmes across the country. Most of the heart failure programmes in our country are often conducted using basic equipment. Full credit needs to be given to the various perfusion units who think out innovative strategies making supra-optimal use of available equipment and resources, far more than what was conceived possible in other countries, yet producing tangible results comparable with international standards. This in my opinion needs to be clinically documented and presented for updating clinical standards of practice. As regards to the availability of equipment for enhancing professional training, most of such equipment are already becoming part of the inventories of different cardiac surgical units across the country. So even though we sometimes may not have the best, we should always try to do the best with available resources and most importantly highlight our experience which could possibly culminate in updation of clinical practice guidelines. As Editor of your journal you have responsibility to encourage and elicit articles from the Perfusionists. I am sure the Editor of the IJTCVS can provide valuable guidance to you and your team. I can facilitate this process at the next Annual Meeting.

10 Finally, what advice would you like to give to budding youngsters and veteran perfusionists alike?

Answer: My advise would be to always consider yourselves as part of the team. With the changes in overall clinical approaches, the team members will need to incorporate more skill sets in to their day to day practice so I would strongly recommend the perfusionists to adopt multi-tasking skills, even while retaining their core speciality of clinical practice. It definitely goes a long way in recognizing professional contributions to the growth of the unit, adding more value to one's professional career and the overall success of the team. You were, are and will continue to be an integral and indispensable part of the cardiac surgical community. Thank you

I thank you for sparing time out of your busy schedule and deeply appreciate your valuable insights shared in this interview.



ECHOCARDIOGRAPHY- RELEVANCE TO A PERFUSIONIST



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Peri-operative echocardiography is the crux of cardiac surgery. Successful outcomes predominantly depend on good echocardiography assessment of the cardiac lesions in both adult and paediatric population. Over the years, this modality for diagnosis, which was limited to the pre and post-operative period has steadily become an integral part even in the operating rooms. This was after the introduction of Trans-oesophageal Echocardiography (TEE) probes. It's important for every speciality present in the operating room to know the diagnosis as well as the echocardiographic assessments of their patients. Such an exercise will help each speciality including the surgeons, anaesthesiologists and perfusionists to prepare and plan the surgery in an organised manner. Therefore it was thought vital to write this editorial to guide the clinical perfusionist, to what exactly he/she should look for in an echocardiogram throughout the peri-operative period.

It is beyond the scope of this editorial to cover all the topics here, however an effort is made to try to cover as much as is relevant in day-to-day practice. For the sake of convenience the echocardiographic relevance for a perfusionist is described in 2 phases: the pre-cardiopulmonary bypass (CPB) & the post-CPB period and further sub-divided each for adults and paediatrics.

Pre-CPB Echocardiography Relevance:

It is a routine for a perfusionist to discuss the plan of surgery well in advance with the surgeon. However, it may not always be possible to do so and one may fall short of time to prepare adequately prior to the case. In such cases apart from knowing the diagnosis it is vital to know the pre-operative Trans-thoracic echocardiography (TTE) or visually assess the pre-operative TEE images in the operating room. Following are the parameters one would like to know as a perfusionist before preparing or going on CPB:



A) Adults:

1. *Ischemic heart disease (IHD)* for coronary artery bypass grafting (CABG); check the Ejection fraction (EF) of the heart and visually assess the myocardial contractility along with regional wall motion assessment (RWMA) on pre-operative TEE.

Relevance: if the plan is for Off-pump CABG and the EF borderline then CPB must be kept stand-by especially for grafting of the posterior vessels (Obtuse marginal OM, Posterior Descending Artery PDA) where the heart is lifted. The need for Intra-aortic balloon pump (IABP) has to be kept in mind. Utmost care has to be taken during giving cardioplegia to avoid distension of the heart, as this would increase the myocardial oxygen demands and thereby induce further stress on the already compromised myocardium with blocked arteries.

2. Valvular heart defects for repairs and replacements; Check for the valves involved. Mitral valve diseases can be isolated or can be sequelae of IHD, ischemic Mitral Regurgitation. The later may prolong the period of CPB, as it would involve the repair of the mitral valve too. Mixed valvular lesions are common findings on TEE and plan for repair/replacement of both valves should be known. Presence of Aortic regurgitation (AR) would cause left ventricular (LV) distension during cardioplegia delivery and root-plegia should be avoided. Retrograde or ostial cardioplegia might be an option. In long-standing stenotic lesions of the aorta or aortic valve and in the presence of LV hypertrophy on echocardiography, myocardial protection may be compromised due to inadequate delivery to the hypertrophied muscle and hence other strategies like cooling may be needed.

3. Minimal invasive surgeries: Mal-positioning of arterial, venous cannulas and cardioplegia cannulas can be identified in TEE before initiation of CPB.

4. The pulmonary artery pressures (>50 systolic) and the grade of diastolic dysfunction (>3).

Relevance: The higher these values and grades are, the more difficult and gradual the weaning from CPB has to be anticipated.

5. *Aortic Atheromas, Aneurysms and Dissections for repairs;* Check for presence of calcifications, atheroma's in the ascending aorta at the site of aortic cannulation, the extent of damage or involvement of the aorta; ascending, arch or descending in dissections or aneurysms on the TEE. This information may help you plan the cannulation sites e.g. Femoral, Brachiocephalic etc. and also prepare you for periods of Total circulatory arrest (TCA). Also, presence of calcifications or atheroma's (Grade 4 & 5) may lead to embolization and stroke (1). Ultra-filtration devices and cell-savers can be kept readily available in the operating room.

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B) Paediatrics:

1. *Defects:* Presence of left superior vena cava (LSVC) on TTE or TEE may warrant a need for an additional drainage cannula. Following details of a Ventricular Septal Defect (VSD) on echocardiography may guide you on the difficulty of its closure and hence prolonged pump runs.

- Mutiple VSD's
- VSD with inlet or posterior muscular extension
- Large Apical VSD
- Double Outlet Right Ventricle (DORV) VSD
- VSD with severe Aortic Regurgitation



2. Tetralogy of Fallot (TOF): Lot of information can be derived form a pre-operative TTE or TEE in a TOF. An echocardiography report will always have 'Z-Scores'. These scores are given to any circular structure (e.g. vascular structures, valves and chambers) for a given body surface area. A negative score denotes hypoplasia (e.g. Pulmonary arteries, pulmonary valve) & a positive score denotes dilatation (e.g. aortic valve, mitral valve). Usually, a pulmonary valve with a Z-Score of -2 above would need a trans-annular patch, increasing the duration of surgery. Also, a dilated left atrial chamber indicates presence of collaterals. This may be evident by increased blood in the field after atriotomy on a quite heart warranting the need for an additional pump sucker or drifting the temperature low to facilitate reduction in the pump flows.

3. *Aortic Arch Anomalies:* This subset may include hypoplasia of aortic arch at different locations and this information will guide you to plan the cannulation sites, cannula size and the type of perfusion required for cerebral perfusion/protection (antegrade or retrograde). Plan for TCA can be ready.

4. *Complex Congenital Lesions:* It is always good to know the presence of Patent Ductus Arteriosus (PDA) or Multiple aorto-pulmonary collateral arteries (MAPCA'S) in the pre-operative echocardiography. This may warrant the need for higher flows on CPB till these shunts are tackled. In Transposition of great arteries (d-TGA) it is prudent to know the anatomy & functionality of the LV in the pre-operative 2-D echocardiography or also on TEE if a micro-TEE probe is inserted. For example, the LV shape/ geometry, LV posterior wall thickness, LV mass index, inter-ventricular septal thickness are some parameters to be noted (2). If these values define the LV as regressed, chances of the child going on ECMO or Left heart bypass after CPB are high. Some institutes are prepared with integrated ECMO circuits in such cases to save time (3). Cannulation strategies may vary in anatomical variants of Truncus Arteriosus or Aorto-pulmonary windows.

Post-CPB Echocardiography Relevance:

This section would focus mainly on the post-repair echocardiography comprising of TEE or Epicardial echocardiography in neonates. Successful weaning from CPB can be done only if complete correction is achieved. The only way to know this is by echocardiography.

A) Adults:

- 1. Regional wall motion abnormalities and EF after grafting should be compared post-grafting. Any worsening should alert revascularisation of the affected territory.
- 2. Valves; assessment of adequate valve repairs/replacement or worsening should be watched for as a perfusionist which would be an indicator to go back on CPB.
- 3. Ventricular dysfunction (contractility); to be correlated with the inotropes, this will guide the perfusionist to support the heart on CPB till recovery is visualised on the TEE.
- 4. Presence on air in the left heart; may guide about the adequacy of venting.



B) Paediatrics:

1. Presence of residual lesions (defects or obstruction) maycause problems in weaning. Lot of studies have reported the effectiveness of detecting residual lesions after CPB in paediatric population. The detection of significant residual defects was reported to range from 4.4-14.4%(4,5)

2. Ventricular Dysfunction; severe LV and/or RV dysfunction can occur in the post-CPB phase. Based on the severity on TEE and hemodynamics a decision to prolong the "Rest-period" on CPB may be taken. However, if the subsequent TEE images do not show an improvement in the function, one should be prepared for initiating an ECMO.

It would also be beneficial to mention briefly about intra-operative Epicardial echocardiography here, especially in the paediatric population as micro or paediatric TEE probes may not always be available. This modality obtains superior quality images by placing the conventional Trans-thoracic echocardiography probe directly on the anterior surface of the heart under sterile conditions. As a perfusionist its important to know that such a modality of echocardiography exists and can be suggested for use in the absence of a TEE probe even in adults. The images can be interpreted on similar lines as TEE and relevant information can be gathered by the entire team.

Conclusion

To summarize, it is important for a clinical perfusionist to discuss the salient findings obtained in an echocardiogram during each phase of surgery with the surgeon or anaesthesiologist. A clinical perfusionist having a sound peri-operative echocardiography knowledge will be better prepared to manage a case, thus making a difference in the patient outcomes.

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Invited Article/Guest Article

Understanding the role of cardiopulmonary bypass in neurological injuries after cardiac surgery



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Overview

Brain Hypoperfusion is the principle reason of neurological complications after cardiac surgery which is an international health concern. Many patients undergo cardiac surgery experience neurological injury as a consequence of hypoperfusion which could emerge from (anatomical structures, side effects of medications administered during cardio pulmonary bypass (CPB), circuit configuration and suboptimal perfusion management during CPB).

Cognitive dysfunction is the most common clinical manifestation of brain injury after cardiac surgery. Its occurrence is related to a combination of three factors that are often associated with cardiopulmonary bypass (CPB): embolism, hypoperfusion, and the inflammatory response.

Neurological injuries are correlated with increase in patient hospital length of stay, expenses and admissions to rehabilitation facilities. Within the range of 1-6 percent, the most feared neurological complication of cardiac surgery is stroke. However, subtle decreases in neurocognition and impairments in level of consciousness occur frequently in the early postoperative period and can be equally distressing for patients and their families. Impaired consciousness may result in further neurological sequelae, including encephalopathy, delirium, and depression.

MECHANISMS AND CAUSES OF CEREBRAL INJURY

The development of extracorporeal devices has been influential in advancing cardiac surgery. However, shortly after widespread CPB practice, neurologic complications were described.

Hypoperfusion-secondary to the emboli or hypotension, low-flow rates and shunting typically results in the CPB complications due to circuit settings. The relatively elevated incidence of cognitive impairment after CPB leaves this an appealing future endpoint. Besides being a tribute to collaboration between biomedical engineers and clinicians, the contemporary CPB system provides an extremely complicated and efficient way of improving the quality of lives and preservation of hundreds and thousands of patients around the world annually. We examine the CPB circuit by its different components:



Oxygenators:

Modern oxygenators have integrated arterial line filter (ALF), Integrated oxygenators equipped with a recirculation line for de-airing purpose. It is the manufacturer's recommendation to keep recirculation lines open during CPB. Recirculation lines are circuit shunts that cause blood to escape from arterial to venous side which in turn leads to hypoperfusion. Sampling manifolds are another cause of shunting that may lead to hypoperfusion.

Hemofilter:

During CPB, the hemofilter flow should be considered if it is connected to the arterial side. One of the The option is connect the hemofilter to the venous reservoir outlet and controlled by a separate pump.

Aortic cannula:

The selection of aortic cannula plays a major role in preventing circuit shunting that causes hypoperfusion, selection of undersized aortic cannula will create high resistance which will eventually increase shunting of arterial flow.

Cardioplegia Delivery System:

During the administration of the blood cardioplegia The perfusionist should consider that the plegia flow will affect the actual arterial blood flow if the delivery system is connected to the arterial side.

Occlusion:

Pump manufacturers recommend setting roller pump occlusion such that the level of a 100 cm column of crystalloid drops 2.5 cm/min, Though this almost occlusive setting ensures accurate pump flow.

ANATOMY

Anatomy plays an important role in shunting blood from systemic to pulmonary flow, resulting in patient-level hypoperfusion. Some of the anatomical defects that may trigger bypass shunting are split into cardiac congenital or adult vascular defects Aortopulmonary (AP) window, Aortopulmonary Collaterals (MAPCS), Patent Ductus Arteriosus (PDA), Truncus Arteriosus (TA), and Subclavian Steal syndrome, especially in adult. In these scenarios, we must bear in mind that portion of our systemic flow is shifted to either primarily pulmonary or secondary systemic circulation (Subclavian Steal Syndrome), which leads to hypoperfusion and thus affects the post-bypass performance of human lives.

Aortopulmonary (AP) Window:

An aortopulmonary window is arare congenital heart defect in which there is a connection (window) between the aorta and the main pulmonary artery. This opening allows oxygenated blood to pass, or shunt, from the aorta into the pulmonary artery at high pressure. The size of the communication determines the symptomology. Excessive blood flow from the aorta into the pulmonary artery can contribute to pulmonary hypertension and heart failure, through the aortopulmonary window. This window is usually closed by separating the great vessels individually. For equipment selection that might require it to achieve a cardiac index of 3.5 L/min/m2 the perfusionist must maximize anticipated pump flow in such cases. Higher pump flow may be needed until the window is controlled to compensate the pulmonary flow. The branch pulmonary arteries are generally controlled before or shortly after going on bypass since a pulmonary flow may jeopardize systemic perfusion. In such instances, near-infrared spectroscopy (NIRS) is needed as a tool for ensuring adequate perfusion in the brain.



Major Aortopulmonary Collaterals (MAPCs):

Major aorto- pulmonary collaterals (MAPCs), especially if the blood flow of the pulmonary artery is inadequate, can grow among the aorta (or other systemic arteries) and the pulmonary circulation. These MAPCs may grow in a number of situations, but they are most frequently linked with pulmonary atresia (PA or TOF / PA) or discontinuous pulmonary arteries. They can also evolve with other abnormalities, particularly in patients with single-ventricle physiology (Fontan circulation). MAPCs of the ships of the head and throat are of special interest since this may lead to poor cerebral blood circulation by systemic flow into the pulmonary system. Depending on anticipated collateral blood flow, the perfusionist must consider the equipment capable of providing cardiac index blood flow of $3.5-5L/\min/m2$. Some aortopulmonary collaterals cannot be accessed, so an enhanced pump flow throughout the operation is necessary. MAPCs are often corrected (unifocalized) or controlled with vessel loops before bypass. Whenever possible, MAPCs should be corrected or controlled, as they cause systemic blood flow shunting in the pulmonary system. In order to ensure an appropriate systemic flow, pump flows may require significant increases.Collaterals of the head and neck are more likely than others to be unifocalised as they influence brain perfusion. In such cases, the Near Infrared Spectroscopy (NIRS) is a means of ensuring adequate cerebral infusion.

Patent Ductus Arteriosus (PDA):

The ductus arteriosus is a connection between the aorta and left pulmonary artery, which is normal and required for fetal circulation. Usually it closes shortly after birth. There is a need of higher pump flow rates to provide adequate systemic perfusion as the blood is shunting to the pulmonary compartment through ductus arteriosus until the ductus arteriosus is controlled. The perfusionist must confirm that the duct is closed before handling low blood pressure pharmacologically. If an alpha agent is administered before ductal closure, the shunt from systemic to pulmonary circulation increases and the blood pressure on the other hand, as the ductus is ligated, and may not be acceptably high. Near-Infrared Spectroscopy (NIRS) is required in such cases as a tool to ensure adequate cerebral perfusion.

Truncus Arteriosus (TA):

In this defect, a single common blood vessel (Truncus arteriosus) comes out of the right and left ventricles, instead of the normal two individual blood vessels in the presence of a VSD. From this common trunk emerges the aorta and pulmonary arteries. Surgical correction is aimed at closing the VSD, ensuring a competent truncal valve, providing pulmonary blood flow with a right ventricle to pulmonary artery conduit incorporating the PAs removed from the truncus and patching the aorta where the PAs formerly arose. The pulmonary arteries must be controlled before or immediately after going on bypass since shunting to the pulmonary circulation can compromise systemic perfusion. Near-Infrared Spectroscopy (NIRS) is required in such cases as a tool to ensure adequate cerebral perfusion.

Subclavian Steal Syndrome (SSS):

It is a series of signs and indications that are caused by retrograde blood flowing from the vertebral artery or the internal thoracic artery because of proximal stenosis and/or occlusion of subclavian artery. At the cost of the vertebro-basilar flow, the arm can be provided by blood running retrograde down the vertebral artery. This is known as subclavian stealing. It is worse than normal vertebra-basilar inadequacy. SSS results when a short path of low resistance (along the subclavian artery) is transformed into a high resistance path (by narrowing) and blood flows around the narrowing through the arteries supplying the brain (left and right vertebral artery, left and right internal carotid artery). This is due to the collateral vessels. Usually, blood flows into the subclavian artery from the aorta, then some blood enters the brain through its vertebral artery. The amount of blood passes through the proximal subclavian artery decreased in Subclavian Steal System. As a result, blood travels up one of the other blood vessel into the brain (the other vertebral or carotid), reaches the basilar artery or goes round the cerebral arterial circle and passes down to the subclavian (proximal blocked) through the (contralateral) vertebral artery, supplying the upper limb and shoulder with blood to the distal subclavian artery.



In rare circumstances, unilateral reversal of vertebral flow may cause vertebrobasilar ischemia transient attacks. The reversal of bilateral vertebral flow was linked to non-lateralization of cerebral ischemia. Subclavian stealing may also occur as vertebrobasilar insufficiency or as limb claudication, usually. In such cases, Near-Infrared Spectroscopy (NIRS) is necessary as a tool for ensuring adequate perfusion of the brain.

Perfusion management

Partial pressure of Oxygen (PaO2):

Both, alveolar hypoxia and arterial hypoxemia induce pulmonary vasoconstriction. A PaO2 lower than 50 mmHg increases pulmonary vascular resistance over a wide range of arterial pH; however, this effect is enhanced when pH is lower than 7.40. Conversely, high levels of inspired O2 can reduce an elevated PVR.

Partial pressure of Carbon Dioxide (PaCO2):

Carbon dioxide is a potent cerebral vasodilator and pulmonary vasoconstrictor. Hypercarbia increases the pulmonary vascular resistance (PVR), independent of changes in arterial pH. On the other hand, hypocarbia reduces PVR only through the production of an alkalosis. In reality, reliable reductions in PVR and increases in pulmonary blood flow and PaO2 are seen in children with Right-Left shunts when hyperventilation to a PaCO2 near 20 mmHg and a pH near 7.60 is obtained. Similarly, post bypass hyperventilation to a PaCO2 of 20–33 mmHg and a pH of 7.50 to 7.56 in patients with preoperative pulmonary hypertension results in a reduction in PVR when compared with ventilation that produces normocarbia or hypercarbia.

pH-stat:

CO2 solubility in blood increases with the lowering of body temperature and vice versa. The reduction in PaCO2 causes an alkaline pH yet remains the same overall CO2 content. Either the gas flow is decreased or CO2 is introduced to the CPB circuit in attempt to preserve normal pH. In pH-stat strategy, pH is adjusted to 7.4 and PaCO2 at 40mmHg according to patient's actual body temperature. Cerebral vasodilatation is triggered by the pH-stat above metabolic requirements and perhaps quicker homogeneous cooling, therefore, patients undergoing hypothermic bypass with pH stat management may benefit from improved tissue-level offloading of oxygen, increased brain blood flow and improved brain cooling. A decrease of blood flow into the pulmonary circulation is particularly important for patients with aortapulmonary collaterals, known or even undiagnosed. This should be taken into account regardless of the strategy used for blood gas. NIRS monitoring may be particularly helpful for these cases. Lower than expected NIRS values may be improved by raising the PaCO2 to the patient's normal level.pH-stat reduces pulmonary blood flow, which even during complete bypass can occur because of collateral circulations. This clearly has the advantages of preventing blood from being stealed from the brain.

Blood Sugar Management:

Elevated blood sugar level is another culprit for hypoperfusion. As it is well known once the blood sugar increases loss of vascular tone happens which in turn causes vasodilatation and hypoperfusion leading to increased lactate levels and vice versa. So the perfusionist must control the blood sugar level when it starts to raise above 180 mg/dL otherwise it will lead to hypoperfusion.

Medications

For acceptable flow rates for CPB, MAP is generally targeted at ~50 mmHg; for older and cerebrovascular patients, a higher target can be selected. Low or high blood pressure episodes during CPB were combined with the neurological and other adverse effects. If MAP falls below the target range, the perfusionist can increase pump flow at acceptable CPB flow



rates, particularly when it is < 2.4 L / minute / m2. If the hypotension remains after increased pump flow, an intravenous (IV) or continuous infusion vasopressor can be used to increase the blood pressure. These vasopressors can cause severe vasoconstriction which leads to hypoperfusion.

Epinephrine (Adrenaline):

Epinephrine is an alpha-Adrenergic Agonist, and beta-Adrenergic Agonist, and Catecholamine. The mechanism of action of epinephrine is as an Adrenergic alpha-Agonist, and Adrenergic beta-Agonist. Epinephrine triggers vasoconstriction by stimulating alpha-adrenergic receptors, thereby raising vascular resistance and blood pressure. The binding of α -driven receptors inhibits pancreatic insulin secretion, stimulates liver and muscle-related glycogenolysis, stimulates glycolysis and inhibits glycogenesis-mediated insulin in the muscles. Binding the β -adrenergic organ causes glucagon secretion into the pancreas, enhanced pituitary secretion of the adrenocorticotropic hormone (ACTH), and enhanced lipolysis adipose tissue. Together, these impacts contribute to higher blood sugar and fatty acids, which produce energy in cells all over the body. The heart has a predominance of β 2 receptors in the coronary artery, which in the presence of epinephrin cause vasodilation of the coronary arteries. Its actions are to increase peripheral vasoconstriction by the receptor α 1 and to increase the cardiac output by binding it to β 1 receptors. The objective of reducing peripheral circulation is to raise the pressure on the cerebral and coronary perfusion and therefore to increase the cardid peripheral of oxygen. Although aortic, cerebral and carotid circulation pressure is increased, epinephrine reduces the carotid blood flow and endtidal carbon dioxide. Epinephrine tends to improve macrocirculation at the cost of capillary beds, where real perfusion occurs.

Norepinephrine (Noradrenaline):

Norepinephrine is an endogenous catecholamine. It has powerful inotropic and peripheral vasoconstriction effects. It increases both systemic and pulmonary vascular resistance. It stimulates $\alpha 1$ and $\alpha 2$ adrenergic receptors to cause blood vessel contraction, thus increases peripheral vascular resistance and results in increased blood pressure. This effect also reduces the blood supply to gastrointestinal tract and kidneys. Norepinephrine acts on beta-1 adrenergic receptors, causing increase in heart rate and cardiac output. However, the elevation in heart rate is only transient, as baroreceptor response to the rise in blood pressure as well as enhanced vagal tone ultimately result in a sustained decrease in heart rate. Norepinephrine acts more on alpha receptors than the beta receptors.

Neosynephrine (Phenylephrine):

Phenylephrin is a noncatecholamine synthesized αl agonist, generates a dose-dependent vasoconstriction of mesentric, splanchic and renal blood vessels. Systemic blood vasoconstriction, with bradycardia reflex raises the systolic, diastolic and mean arterial blood pressure. Phenylephrine may also trigger pulmonary vasoconstriction and pulmonary hypertension.. Since phenyléphrine constricts the larger arterioles and not terminal arterioles, microvascular perfusion may be better than norepinephrine. Phenylephrine can trigger serious necrosis by infiltrating the adjacent tissues, because of its vasoconstrictive impact. Blood pressure is increased primarily by enhancing systemic vascular resistance without the corresponding rise in myocardial contractility.

Conclusion :

Brain hypoperfusion is a serious condition, it has short and long term complications , it happens due too many causes , could be due to medications , anatomy , blood gas correction management or mechanical techniques used during the invasive treatment of the patient .Newer methods of patient monitoring hold promise for providing an improved method of individualising and management to ensure that it remains within cerebral blood flowautoregulatory limits during surgery.



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Invited/ guest article

MYOCARDIAL PROTECTION: EVOLUTION AND CHANGING TRENDS



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Abstract

Myocardial protection has always been an enigma for ages. Right since the time of Melrose discovering and coining the term cardioplegia till the current off pump CABG, myocardial protection has gone through various phases and has constantly evolved. This article gives a brief overview about the various CP techniques, the CP additives and the techniques associated with it. Still future holds a great scope and room for improvement in this field with more techniques and research rapidly evolving for sick patients.

Key words:

Additive; cardioplegia; blood; crystalloid

Introduction

The cornerstone of cardiac surgery, myocardial protection is the most important factor contributing to the overall outcome of the surgery. Evolution of cardiac surgical practices have revolved around this most important factor. The article describes the evolution and futuristic perceptions of myocardial preservation techniques, especially emphasising on cardioplegic techniques.

Hypothermic Cardioplegia (CP)

Initially cold crystalloid cardiolplegia was developed in order to arrest the heart, provide a comfortable surgical field for anastomosis and also to ensure that the myocardial injury during arrest was kept to a minimum by the additives in the cardioplegia (1). But later, people found that this alone was not enough and hence the search for newer techniques began in the horizon.

Blood Cardioplegia

This search began by incorporating blood into the CP delivery system which rapidly compensated for the substrate oxygen carrying capacity which was not present in the crystalloid CP. This first came in the 1980s when Fremes and colleagues found by experimental data that blood CP had a lesser lactate production than the crystalloid CP which might be explained by the anaerobic metabolism during crystalloid CP. (1). Future studies revealed that blood cardioplegia improved oxygen carrying capacity, enhanced myocardial oxygen consumption and preserved myocardial high-energy phosphate stores (2).

Substrate Enhancement of CP

Later, people found that blood alone was insufficient as there was still a significant amount of myocardial necrosis even with blood CP and the search for substrate enhancement came into picture. The results clearly showed that addition of substrates like glutamate, histidine, tryptophan added to the myocardial protection much better than blood alone (3). In a trial by Rosenkranz and colleagues, hearts arrested using glutamate- supplemented cardioplegia achieved earlier metabolic recovery (3).

Insulin Cardioplegia

It is the rate limiting enzyme Pyruvate Dehydrogenase (PDH) which tilts the balance towards anaerobic or aerobic glycolysis. Insulin is a co factor of PDH and this effect was pretty much demonstrated by the addition of insulin to CP which was shown by the Rao et al (4) study. The insulin CP group had decreased lactate production when compared to the control group and hence lesser post op inotropic requirements and decreased Vaso-active Inotrope Score (VIS). Larger trials are needed to confirm this although this could be an effective substrate enhancement in CP.



Antegrade Normothermic Cardioplegia

Having known about the substrate enhancement and beneficial effects of CP, the next question came regarding the optimum temperature. In 1982, Rosenkranz and coworkers demonstrated that warm induction of cardioplegic arrest improved myocardial metabolic and functional recovery following CABG (3). Teoh and colleaugues from Toronto further proved that before cross clamp release, the induction of "hot shot" which involves normothermic, hyperkalemic perfusate administration aids greater myocardial recovery. This is presumably due to faster recovery of mitochondria (which are the Adenosine Tri Phosphate (ATP) power houses) aided by normothermia. Hence warm induction and enhancement with "hot shot" supplementation can be used in patients with myocardial dysfunction and in cases where prolonged cross clamp time is needed for better myocardial protection.

Warm Heart Surgery

With warm induction showing better benefit, people began to wonder what if the entire surgery was carried on with warm CP instead of using it at induction alone. The work by lichtenstein (5) and colleagues wherein 121 Coronary Artery Bypass Grafting (CABG) surgery patients were consecutively operated with warm CP gave a good impetus to this. They suggested that the heart be maintained at a temperature of 37°C throughout the cross-clamp period to enhance perioperative myocardial metabolic function. The metabolic needs of the heart, in turn, would be met using near continuous cardioplegic methods. In comparison to a historical cohort of 133 patients receiving hypothermic antegrade blood cardioplegia, patients in the warm group revealed a decreased incidence of perioperative myocardial infarction and intraaortic balloon pump requirement, despite cardioplegic interruptions approaching 15 minutes in duration (5).

Optimal Delivery of Antegrade Normothermic Cardioplegia

Having discussed about the subtsrae and temperature, the next focus is to be given on the quantity and flow rate of CP. In a study by yau et al (6), flow rates at more than 80 ml/min with a bloosd to crystalloid dilution ration of 4:1 offered better protection than rates less than 80 mL/min with a blood to crystalloid dilution of 2:1 (or a hemoglobin concentration of 50 g/L). The reason being accumulation of an oxygen debt, anaerobic lactate production and less washout , and a corresponding impairment in myocardial performance with low flow rates and low blood dilution. Thus, effective cardioprotection with normothermic cardioplegia needs higher flow rates (80 mL/min or greater).

Myocardial Preconditioning

Ischemic preconditioning (IPC) is a very good and powerful myocardial protection phenomenon. The coronary snaring technique in off pump CABG works on this principle. Adenosine is a pharmacological mediator of IPC. Lee (7) and colleagues administered intravenous adenosine to patients undergoing elective CABG immediately prior to the initiation of cardiopulmonary bypass and found improved cardiac indices and a reduction in postoperative creatine kinase MB isoenzyme release in comparison to nonrandomized controls. Pre cross clamp treatment with adenosine helps in enhanced ATP recovery evidenced by the study of lee et al (7). A difference of 15% ATP levels was found in the control and the treatment group.

Latest additions to the cardioplegia conundrum include del Nido Cardioplegia and Custodiol-HTK solution which are being used for complex cardiac surgical procedures. Custodiol – a crystalloid based cardioplegic solution also is used as for myocardial preservation during cardiac transplantation procedures. Del Nido cardioplegia solution which is essentially blood cardioplegia but with a reversed blood: crystalloid composition offering longer protective periods with minimal re-infusion requirements was initially used in pediatric cardiac surgery; is also being introduced in Adult Cardiac Surgery as an alternative to classic blood cardioplegia.



Future Perspectives in Myocardial Protection

Current strategies involve substrate manipulation and temperature adjustment which will benefit in simple and straight forward cases while high risk substrates need more attention and better focusing on CP techniques. Thus, future directions in cardioplegic management will likely involve the use of cardioplegic additives to further improve protective effects and mini CP (also known as Micro-plegia) is one such technique which is used for such scenarios.

Conclusion

Current techniques of intraoperative myocardial protection are constantly evolving. To date, changes in cardioplegic composition, temperature, and delivery have been successful in optimizing intraoperative myocardial protection. As such, stable patients presenting for elective coronary bypass surgery face a relatively low risk of perioperative morbidity and mortality. Patients with Left Ventricle (LV) hypertrophy, LV dysfunction, prolonged ischemic times need additional CP additives with further modifications for better myocardial protection.

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Original Article



DEVELOPMENT OF A MODEL FOR ALBUMIN PRIMING IN PEDIATRIC CARDIOPULMONARY BYPASS CIRCUITS



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Abstract

Background:-This study was performed to evaluate the effect of colloidal priming using 20% Albumin . Priming has an advantage of maintaining COP (colloid oncotic pressure) and reducing tissue edema. In this study we compared the effects of using hyperoncotic colloidal priming (Albumin) with routine crystalloid priming solution on CPB in pediatric patients.

Methodology:- 60 patients of weight less than 10 Kg undergoing cardiac surgery were randomly divided into three groups.

In Group A (n=20) circuit was prime with routine crystalloid, Mannitol (5mL/kg body weight) was used, Albumin was added 1mL/Kg variables were measured at different time intervals.

In Group B(n=20) Circuit was primed along with Mannitol (5mL/kg body weight) was used Albumin was added 3ml/Kg variables were measured at different time intervals.

In Group C (n=20) Circuit was primed along with Mannitol (5mL/kg body weight) was used, Variables were measured at different time intervals.

Result: it shows standard attenuation of tissue hypoalbumenia in pediatric patients caused by hemodilution in CPB. This study allow the perfusionist to select the dose of albumin in pediatrics.



Conclusion: We conclude the beneficial effect of albumin priming in Group B has better hemodynamic, postoperative stability as well as it maintains good colloidal oncotic pressure (osmolarity) compared to Group A and C.

Keywords: Colloid osmotic pressure (COP), CardiopulCorresponding Author

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Introduction

In the cardiac surgery, cardiopulmonary bypass is necessary for the majority of the congenital cardiac defect. Cardiopulmonary bypass involves connecting the circulation of a patient to an extracorporeal circuit that take the function of the heart and lungs during the surgery. Prior to being connected to the patient's systemic circulation, the cardiopulmonary bypass circuit must be primed with a solution that will mix with the patient's blood at initiation of cardiopulmonary bypass. This is typically done with an isotonic crystalloid fluid,Ringer's solution or Plasmalyte A, along with certain additives. These are typically include heparin, manintol, sodium bicarbonate and albumin. Although each of these has their role and recommended dose.

Albumin is a naturally occurring plasma protein within the human body that is critical with regard to the maintenance of colloid oncotic pressure and transport compounds. It is added to the prime of a cardiopulmonary bypass circuit to reduce the drop in colloid oncotic pressure (COP), haemodilution occur when the patient's circulating blood volume is diluted by the crystalloid prime solution.^{(1).}

If a significant drop in colloid oncotic pressure occurs, it would result in a large fluid shift from the intravascular space into the interstitial space⁽²⁾. This fluid shift results in edema, and has been shown to lead to more severe outcomes, such as post-operative organ edema and dysfunction^(1,2,3), extravascular lung water^(1,2,4) and weight gain.^(5,6,7).

It can therefore be predicted that a deficit in circulating albumin would result, to some degree, in these adverse outcomes. The practice of adding albumin to the prime of the perfusion circuit is still debatable widely varying patient parameters, such as blood volume and patient albumin concentration, complicate the potential for a universal practice of adding albumin to each prime. The potential for a universal practice is even further complicated in pediatric cases, where circuit volumes are proportionally much greater than patient blood volumes, creating a threat of extreme dilution of blood, as well as albumin.

Pediatric patients also have a greater vascular permeability, and they often require hypothermia during cardiopulmonary bypass. All of these factors provide reason as to why an albumin dosing protocol in pediatrics is so complicated and simultaneously also critical. The goal of this study was to explore the importance of albumin in a pediatric circuit prime, and attempts to develop a comprehensive circuit for albumin dosing in the priming of pediatric cardiopulmonary bypass circuit. Pediatric patients have a slightly different physiology than adult patients, and thus cause them to be sensitive to the effects of a hypooncotic cardiopulmonary bypass prime. These factors include an overall physiologic immaturity, increased metabolic demand, and a high vascular permeability. Their immature myocardium makes them more vulnerable to myocardial injury, especially in the face of their innate increased metabolic demand, which requires an increased cardiac index⁽⁸⁾.


Their increased vascular permeability allows for fluid to shift into the interstitial space more easily, especially during times of low colloid oncotic pressure. These physiologic factors make a pediatric patient more prone to edema during bypass. It is also important to mention that pediatrics have a proportionally larger blood volume per weight than adults do. This higher proportional blood volume results in a higher blood volume per weight and affects the blood volume difference between adult and pediatric perfusion is the extreme temperature manipulation typically utilized in pediatric surgery, due to the level of complexity that congenital defect repairs involve. Commonly, deep hypothermia with circulatory arrest is used. Such temperature changes imposed upon the human body are correlated with edema formation(9) via activation of the complement cascade and prompt leukocyte degranulation. Each of these results in endothelial injury, and therefore increased capillary permeability. An increased capillary permeability allows for fluid to shift more easily into the interstitial space, especially in a low colloid oncotic pressure environment. Hypothermia also induces vasoconstriction and an increased viscosity of the blood, causing an increased hydrostatic pressure, and a higher tendency for fluid to be pushed through to the interstitial space⁽¹⁰⁾.

Vascular permeability is also thought to be increased in pediatrics due to capillary leak syndrome, a phenomena where an immune response is elicited due to the trauma of surgery, exposure to the cardiopulmonary bypass circuit, and ischemic reperfusion injury, resulting in vascular excavation and edema^{(11).}

Normally, 40% of albumin is in the intravascular space, and 60% of albumin is in the extravascular space; however, the extravascular space contains much more volume than the intravascular space, and therefore, counter intuitively, has a lower concentration of albumin(12,13). Albumin normally does not permeate the endothelial barrier due to its large size (66,248 daltons), although any albumin that does leave the capillary is returned to the circulation via the lymphatic vessels^(14,15).

	Albumin 20%	
Mw(Daltons)	69,000	
Mn (Daltons)	69,000	
Osmolarity (mmol)	300	
COP (mmHg)	29	
T ½ (hr)	162	
Duration of PVE(h)	8	
Elimination(h)	17 Days	

Table 1: Physicochemical characteristics of albumin

COP=Colloid osmotic pressure ; T1/2 con.= Half-life of concentration ; Mw= weight average molecular weight ; Mn=number average molecular HES= Hydroxyethyl starch ; PVE = Plasma Volume Expansion



The most important function of albumin is to maintain colloid oncotic pressure. Colloid oncotic pressure is the pressure exerted by plasma proteins (notably albumin) in the intravascular space,(16,17) that tends to shift fluid out of the capillary and into the interstitial space.

Plasma colloid osmotic pressure is determined by the molecules or ions that are unable to pass through the pores of a capillary membrane. It acts to pull fluid out of the interstitial space, and into the intravascular space, and it is opposed by the colloid osmotic pressure of the interstitial fluid.(15) In healthy adults, the colloid osmotic pressure is approximately 28mmHg, although some literature suggests that albumin can reach as low as 22 mmHg in healthy adults. Albumin is responsible for approximately 80 percent of the plasma colloid osmotic pressure, while the remaining 20 percent of the plasma colloid osmotic pressure is provided by globulins, which are high molecular weight globular proteins(14).

This explored the development of a model to properly dose albumin in pediatric cardiopulmonary bypass circuit primes. This model was based on the fact that a large dilution of albumin by the circuit prime results in a reduction in colloid osmotic pressure, and results in edema and negative clinical outcomes.

Method & Material

This study was performed in the department of CTVS, AIIMS New Delhi and the study period was approximately 7 months. We had permission and duely signed by the institutional ethics Committee for the study with reference no. IECPG-58/28.02.2018, RT-38/21.03.2018. All the patient has been informed (PIS) and consent has been taken by signature on (PICF).

Study was performed on 60 pediatric patients undergoing Cardiac surgery of either sex in the range of weight not more than 10 Kg. Patients were divided in three Groups -A, B and C. 20 patient in each group and the albumin dose is as follows:

- Group A 1 gm/kg which is normal clinical dose
- Group B was given 3 fold higher dose which is 3 gm/kg.
- And group C albumin was not added in it.

Inclusion Criteria-Body weight of the patient will be > 10 Kg.

Exclusion Criteria-Any systemic disorder of disease except cardiac and patient having body weight less than 2Kg.

Statistical analysis was performed on SPSS (version 11.5) software and Bonferroni test for normal data was performed. Bartlett's test is used to test difference between the means of two groups on a single variable. If there are significant differences between groups, the other comparisons between groups were performed by the t-test. p value of less than 0.05 is considered statistically significant.



PARAMETERS	GROUP A	GROUP B	GROUP C	P Value
AGE (years)	8.8±7.68	9.75±7.46	11.8±12	0.37
HEIGHT (cm)	64.5±12.6	67.6±16.7	69.7±8.45	0.45
WEIGHT (Kg)	5.65±2.44	6.5±2.69	6.86±1.95	0.25
$BSA(m^2)$	0.33±0.14	0.3±0.11	0.3±0.69	0.71
Bypass Time	75±29.1	99.8±41.5	71.4±19	0.01
AOXL	46±16.3	58±22.4	45.4±14.8	0.05

Table 2: Demographic data

Group A was primed by 1ml/Kg and Group B was primed by 3ml/Kg

*Mean \pm standard deviation values are taken for the analysis

*P value <0.05 are significant

B.S.A-Body Surface Area

NS: Non Significant

Result

The results are In (Table 3) their is no significant parameter except pO2, hemoglobin and Mean arterial pressure. The pO2 is showing p value of 0.01 and hemoglobin in group A, group B, Group C are 11.7±2, 12.4±3, 10.1±1.9 and having P value 0.01 Mean arterial pressure is also showing p value of 0.01 which is significant.

In (Table 4) is showing data after clamp on in which it is showing more changes in the group B which is having higher dose of albumin, showing variation in Hemoglobin 11.4 \pm 1.5 in group B which is more than other groups, having P value of 0.01. It is observed that urine output is also increased in this group 71.8 \pm 82.7 due to increase in osmolarity, showing P value of 0.03. Haemofiltered volume is also more, showing P value 0.01 which is significant in this group.

In (Table 5) which shows the 24 hours of ICU stay, there is only statistical significant difference of Haemoglobin P value of 0.05, although in Group B increased osmolarity is showing where higher dose of albumin is used but there is no statistical significant difference.



Parameter	Group A	Group B	Group C	P Value
pH	7.39±0.2	7.32±0.1	7.32±0.1	0.59
pCO2 (mmHg)	35.6±2.41	43.9±22	42.1±15.6	0.21
pO2 (mmHg)	208±71	192±47.1	175±62	0.01
BE	-4 ± 0.95	-1.94±4.80	-3.38±3.7	0.18
Na+	134.9±2.65	135±2.8	132.9±12.9	0.58
K+	3.41±068	3.58±0.71	3.58±0.760	0.68
Hb (g/dl)	11.7±2	12.4±3	10.1±1.9	0.01
Osmolarity(mOsm/L)	273.2±3.38	270±7.39	271.8±6.86	0.49
MAP	67.2±7.3	67.3±11.3	59.2±10.4	0.01
Sugar	110.4±26.03	109.6±23.6	113.2±30	0.9
Lactate	1.37±0.51	1.21±0.42	1.50±0.82	0.33
Ca2+	0.97± 0.13	0.94±0.29	1.07±0.16	0.11
Urine Output	10±4.4	16.25±15.3	12.3±6.20	0.34
Haemofilter	160.7±65.5	260±48.9	240±194	0.11

Table 3: Pre-Operative data

Group A was primed by 1ml/Kg and Group B was primed by 3ml/Kg

*Mean \pm standard deviation values are taken for the analysis

*P value <0.05 are significant

B.S.A-Body Surface Area

NS: Non Significant



Parameter	Group A	Group B	Group C	P Value
pН	7.37±0.02	7.32±0.1	7.32±0.1	0.59
pCO2 (mmHg)	37.9±5.11	37.8±4.75	38.5±5.3	0.88
pO2 (mmHg)	175±62	198.5±56.5	197±66.2	0.4
BE	-0.47±4.1	-0.45±3.17	-0.24±3.1	0.76
Na+	134.9±2.65	135±2.8	132.9±12.9	0.58
K+	3.7±0.37	3.75±0.59	3.7±0.69	0.93
Hb	9.4±1.82	11.4±1.5	11.0±1.7	0.01
HCO3 (mEq/L)	23.1±2.84	32.7±42.8	40.3±73.2	0.56
Osmolarity(mOsm/L)	279.5±6.7	285±5.98	276.6±3.8	0.001
MAP	46.05±6.6	52±12.6	51.6±15.7	0.23
Sugar	110.4±26.03	109.6±23.6	113.2±30	0.9
Lactate	2.62±1.13	2.70±1.05	2.61 ±1.03	0.95
Ca2+	0.97± 0.13	0.94±0.29	1.07±0.16	0.11
Urine Output	15.5±6.61	71.8±82.7	70.5±90.8	0.03
Hemofilter	154.5±41	412.5±244	351.7±249	0.01

Table 4: Intra-Operative after Aortic Clamp(On CPB)

Group A was primed by 1ml/Kg and Group B was primed by 3ml/Kg .

*Mean± standard deviation values are taken for the analysis

*P value <0.05 are significant

B.S.A-Body Surface Area

NS: Non Significant



Parameter	Group A	Group B	Group C	P Value
pН	7.38 ± 0.02	7.36±0.07	7.36±0.07	0.15
pCO2 (mmHg)	44.5±11.2	41.9±14.3	38.8±28.2	0.97
pO2 (mmHg)	175±41	152±52.3	218±115	0.56
BE	0.11±3.65	0.21±3.02	-1.9±3.95	0.1
Na+	139±6.65	139.2±6.56	140.1±4	0.89
K+	3.28±0.5	3.46± 0.51	3.62±0.5	0.12
Hb	10.8±1.5	11.9±1.2	11.7±1.7	0.05
HCO3 (mEq/L)	23.8±1.86	24.2±3.08	23.7±10.4	0.95
Osmolarity(mOsm/L)	285±3.57	295.5± 9.2	276.2±9.8	0
MAP	72.55±10.6	61.3±11.5	69.2±22.1	0.07
Sugar	138.9±45.8	151.46±45	149.6±52	0.67
Lactate	1.68±0.81	2.05±0.94	2.07±1.05	0.33
Ca2+	0.96±0.28	0.97±0.3	1.06±0.11	0.44
Urine Output	181.7±41.7	158.7±121.9	127.5±101.4	0.22

Table 5: After 24 hrs post CPB

Group A was primed by 1ml/Kg and Group B was primed by 3ml/Kg

*Mean \pm standard deviation values are taken for the analysis

*P value <0.05 are significant

B.S.A-Body Surface Area

NS: Non Significant



Discussion

This study is reestablishing the standard criteria to attenuate tissue hypoalbuminemia in pediatrics caused by haemodilution in CPB. This study allow the Perfusionist to select the dose of albumin in routine pediatric practice easily and extend into practice of adult practice also.

In another studies it has been shown that another consideration to help prevent oedema formation would be to utilize pulsatile flow during bypass. Pulsatile flow is a potential setting available on some cardiopulmonary bypass machines that allows for regular, intermittent periods of high-flow and low-flow that attempt to mimic the systolic and diastolic pressure waveform, some studies indicate that oedema formation is decreased when pulsatility is utilized.(18.19,20) Shen et al. found that pulsatile flow significantly decreased oedema and better preserved renal function in cases utilizing deep-hypothermia and low-flow perfusion(21) Several studies support the theory that in low-flow perfusion, pulsatility is especially useful in preventing edema(22) One proposed mechanism for this is that pulsatility increases lymphatic drainage, which helps to attenuate any positive fluid balance in the interstitial space (22) .These pores only allow for molecules up to 20 kDa to pass through and be removed through filtration (23) . Molecules such as sodium, potassium, chloride, urea, creatinine, and glucose all have a molecular weight under 10 kDa, allowing for them to be removed easily (23) Albumin (which is around 66 kDa) and other blood components are too large to be removed through the pores.(23) Therefore, through hydrostatic pressure and concentration gradients, a significant amount of plasma water and electrolytes may be removed, while retaining albumin(24).

Study Limitation

We cannot perform this study in adult patients as the blood volume is larger thus amount of albumin required to prime the circuit is more Due to higher cost and unavailability of albumin, in every pediatric/adult patient. Patients having renal failure and hepatic failure should not prime with albumin.

Conclusion

We found in the study that use of fresh albumin in concentration with 1ml/Kg in group A and 3ml/Kg in group B is safer to prime there is no albumin associated morbidity. Hence to conclude with beneficial effect of albumin priming in Group B has better hemodynamic stability as well as it maintains good colloidal osmotic pressure (osmolarity) compared to Group A and C.

In group B Post-operative haemoglobin (HCT) increases. No significant change in serum lactate. Comparing to other groups reduced use of blood and blood products, shorter duration of mechanical ventilation and length of ICU stay.

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Original Article

COMPARISON OF NEUROLOGICAL OUTCOME AFTER ASCENDING AND AORTIC ARCH SURGERY USING TWO TECHNIQUES OF CEREBRAL PERFUSION, ANTEGRADE SELECTIVE CEREBRAL PERFUSION (ASCP) OR RETROGRADE CEREBRAL PERFUSION (RCP)



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ABSTRACT

Objective:- Antegrade selective cerebral perfusion (ASCP) and retrograde cerebral perfusion (RCP) have proven to be reliable methods of brain protection during ascending aortic arch surgery. These techniques are usually accompanied by systemic circulatory arrest with moderate hypothermia (24-28°C) or deep hypothermia (18-20°C).

Study was to compare the result of ascending aortic arch surgeries, Using two different methods of brain protection, particularly with respect to neurological outcome.

Method:- The total (n=10) patients with aneurysm/dissection of ascending aortic arch replacement were studied. Surgery was performed under deep hypothermic circulatory arrest (DHCA) with either ASCP by right axillary artery and left common carotid artery cannulation or RCP through superior vena cava (SVC). Seven patients (Group A) underwent ASCP and three patients (Group R) underwent RCP.

Result: Ten patients, group R (n=3) and (n=7) from Group A were discharged from hospital without any major complications. All the patients from both groups, after surgery regained consciousness in 12 to 18 hours and were extubated after 20 to 24 hours. All patients were discharged from hospital after 7 to 13 days. No significant differences were observed between both groups regarding neurological outcome. Only hospital stay was more in group R compare to group A.

Conclusion :- ASCP is an effective and safe method of brain protection during aortic arch surgery. Our result suggest that axillary artery cannulation for ASCP is successful and may be the optimal technique for reducing perfusion-related morbidity and adverse outcome in operation for acute dissection, atherosclerotic and degenerative aneurysmal disease. RCP can be used in emergency if gaseous emobolous is seen in arterial line as primitive method.

Key Words:-Antegrade selective cerebral protection, Retrograde cerebral perfusion.



Introduction

Brain damage is a frequent complication in patients who undergo surgery on aortic arch. The surgical repair of an aneurysm or dissection of ascending and arch of aorta is still associated with significant morbidity and mortality due to neurological complications. Since the central nervous system (CNS) is so exquisitely sensitive to anoxia, because the threshold time of ischemia for neurons is 3-4 min only, so, subsequent neurological injury remains the most feared complications of aortic arch repair. The incidence of neurological complications following aortic surgery has ranged in the literature from 5 to 70%1. It is difficult to know which factors have a decisive impact on neurological outcome.

As described by Ergin from the Mount Sinai group, there are mainly two different types of neurological injury which have to be distinguished2. Type 1 is frank stroke which is usually the result of an embolic event and is often not unexpected, since severe aortic calcification is a frequent observation in patient with aneurysm of aortic arch. A typical neurological symptom depends on the location and size of defects as well as on the individual patient variable. Imaging can be via diagnostic MRI, or a computed tomography (CT Scan) as early as 12 to 48 hours. Type 2 of neurological injury occurring as a consequence of aortic surgery has been termed Temporary neurological dysfunction (TND) and is a reflection of imperfect brain protection during circulatory arrest, as demonstrated by a highly significant correlation between TND and duration of hypothermic circulatory arrest2,3.

Based on clinical experience, surgical strategies have changed over time and various techniques including deep hypothermic circulatory arrest (DHCA)4, retrograde cerebral perfusion (RCP)5, and antegrade selective cerebral perfusion (ASCP)6, have been introduced in order to protect the brain tissue from ischemic injuries. DHCA has been used either alone or in combination with various partial cerebral perfusion techniques for intraoperative protection of CNS. Data indicate that cerebral metabolism and cerebral energy state are better after low flow RCP or ASCP than after circulatory arrest alone, i.e. low flow is more physiological than no flow.

The current methods for brain protection include DHCA, RCP and ASCP. All the 3 methods have their own advantages and disadvantages. At the All India Institute of Medical Sciences, New Delhi ASCP and RCP with hypothermic circulatory arrest are the method of choice for cerebral protection, especially for patients requiring complex aortic arch repairs. This study has been undertaken to compare the hospital mortality, Systemic morbidity, and neurological outcome in patients undergoing aortic arch repair with either ASCP or RCP.

Review of litrature

Deep hypothermic circulatory arrest (DHCA)

In 1974, DHCA was first used in Bologna (Italy) by Pierangeli et al8 for the treatment of an atherosclerotic aortic arch aneurysm. DHCA is the most common technique used while operating on the transverse aortic arch2,9 DHCA allows the surgeon to excise the distal clamp site, completely view the aortic anatomy in a bloodless field, and perform a distal anastomosis without leaving any clamp compromised tissue. The primary concept is based on the idea of reducing the brain activity and therefore energy demand – to a minimum. Since enzymatic intracellular reactions are temperature related, cooling reduces the requirement for oxygen delivery and the release of potentially detrimental excitatory neurotransmitters such as glutamate10. The pH and adenosine tri-phosphate stores can also be better preserved at cooler temperatures.

The question whether alpha-stat or pH-stat management during cooling should be used is still a matter of controversy. pH-stat management seems to abolish auto regulation, causing high flow due to vasoplegia and loss of resistance. With this "luxury perfusion", the risk of cerebral oedema increases and also the risk of embolic events. This technique may provide more thorough and sustained cooling of the tissues. Alpha-stat management preserves auto regulation even at low temperatures, mitigates acidosis and may avoid an accumulation of body fluid.



It seems that there is no consensus regarding whether to use alpha stat or pH-state in adult patients for DHCA. Differences in anatomy, especially aorto-pulmonary collaterals, may favor the use of pH-stat management in infants with congenital heart disease, further complicating understanding of this complex issue¹¹. Electro encephalographic silence, the suppression of somatosensory evoked potentials (SSEPs), high jugular venous bulb saturations, defined cooling intervals, and achievement of specific core temperatures are methods used clinically to define what is thought to be adequate metabolic suppression prior to circulatory arrest. Methylprednisolone and barbiturates are frequently administered before DHCA, and the head may be cooled with ice packs to prevent rewarming of central nervous system. With current methods, most clinicians consider 35-40 min of DHCA at 20°C as relatively safe.

Reich et al¹⁴ have confirmed that patients with arrest times longer than 25 min have a higher incidence of TND, and a greater degree of cognitive dysfunction on psychometric testing.

Kirklin JW, Barrat-Boyes (1993) state that a systemic temperature of 20° C to 22° C or less are used to allow cessation of the circulation for periods up to 40-60 minute, often without detectable organ injury¹⁵.

The protective limits of DHCA were further defined in 1993 by Savensson et al¹³ who reported Crawford's experience with 656 patients who underwent DHCA during proximal aortic surgery. The overall rates of transient stroke, permanent stroke, and early mortality were low, but the incidence of perioperative neurologic complications rose sharply when the HCA time exceeded 40 minutes and mortality increased dramatically when DHCA time exceeded 65 minutes.

Retrograde cerebral perfusion (RCP)

During the 1990s, retrograde cerebral perfusion (RCP) became popular as a means of safely extending DHCA times. RCP was first described in 1980 by Mills and Ochsner¹⁷ as a method of treating massive air embolism during CPB.

However the concept of using RCP for cerebral protection as an adjunct to DHCA did not arise until Veeda et al introduced RCP to neuroprotection during aortic arch surgery in 1990^{18,19.}

The theory behind use of RCP is that retrograde flow is established via the superior vena-cava (SVC) during deep hypothermia to increase the cerebral ischemic tolerance and prolong the clinically safe duration of DHCA by providing metabolic support, removing potentially toxic metabolites, and preventing rewarming of brain during the period of DHCA without antegrade flow, the theoretical benefits of adding RCP to DHCA include more homogenous cerebral cooling, washout of air, bubbles, embolic debris and metabolic waste products, prevention of cerebral blood cell micro aggregation, and delivery of oxygen and nutritional substrates to brain tissues20,21. In the years which followed, this popular technique became routine in many institutions, despite a lack of adequate experimental data.

There are two different techniques by which RCP is implemented. First is its use as an adjunct to DHCA, with continuous retrograde perfusion as long as the brain is expected to be ischemic. Several authors claim excellent clinical results 18-22. Other group prefer to flush the cerebral circulation briefly by use of RCP, particularly were the risk of embolic events is judged to be high2. Some discussion has centered on whether the inferior vena-cava should be clamped during retrograde perfusion to avoid volume loss via collaterals, at the cost of brain perfusion.

Katz & coworkers²⁶ showed, in a study that retrograde flow through the SVC reaches the cerebral venous system, but not the capillaries.



Ono²⁷ was able to demonstrate in five patients who underwent aortic arch surgery that fluorescein injected into the SVC cannula could be seen in retinal capillaries and arterioles. Since the retina is a part of the brain, they concluded that RCP provides blood flow for the cerebrum. Comparing the regional cerebral blood flow during RCP and CPB with different methods (e.g. hydrogen clearance and laser Doppler methods) have demonstrated that about 20-60% of hypothermic CPB flow can be achieved via retrograde pathways. An excellent overview with a detailed description of the specific techniques was published by Reich and coworkers in 2001²⁸.

Question of flow, there is still controversy concerning the necessary pressure required to achieve an adequate perfusion. In appears that the effectiveness of RCP increases, if the vena cava is cross-clamped and potential decompression avoided. Clinically the venous pressure is controlled via either a central venous catheter (CVP line) in the SVC (as jugular bulb catheter), and the flow in adjusted to maintain pressure in the range of 20-25 mmHg. Since it was demonstrated by de Brux and coworkers²⁹ in a cadaver study in humans that the jugular vein may contain valves, higher perfusion pressure up to 40 mmHg have been used. But high perfusion pressures flow rates can cause accumulation of tissue fluid and cerebral edema, especially if duration of RCP is prolonged³⁰⁻³². Since it has been shown in a chronic porcine model that higher intracranial pressure during reperfusion are associated with poorer neurological outcome.³³

In a clinical setup, Higami and coworkers³⁴ were able to demonstrate a continuous fall in cerebrovascular oxygen saturation with time during RCP, eventually reaching a critically low level, whereas with selective cerebral perfusion (SCP) there was no time limitation. They speculate that this may be a reflection of increasing tissue edema during RCP, with an adverse influence on oxygen exchange in the capillary bed.

Assessing efficacy of RCP

Human investigation of cerebral metabolism during RCP

Some had measured the oxygen extraction ratio (OER) during RCP. Cheung and associate³⁵ found that the OER increased at the onset of RCP in all patients but, this effect was less pronounced in patients with previous strokes and intraoperative strokes.

Ganzel and associates³⁶ compared DHCA and RCP in small sample of patients, finding that regional cerebral oximetry was comparable between groups. However, Higami and associates³⁴ found that regional cerebral oximetry tended to decrease during the conduct of RCP. In a study comparing RCP in patients at two levels of hypothermia with DHCA and in awake controls, more hypothermic RCP resulted in higher OER compared with awake controls.³⁷ Ueda and associates³⁸ were among the first to report that oxygen extraction and carbon dioxide elimination occurred during RCP.

Human investigation of biochemical markers of neuronal injury. S-100 β is a glial protein that is released into cerebrospinal fluid (CSF) and blood stream during cellular injury. It has been proposed to be a marker of global neuronal injury in cardiac surgery patients. It remains uncertain, however, whether S-100 β levels correlate with measures of neurological or neuropsychological deficits in patients undergoing surgery that requires CPB.³⁹⁻⁴¹

Antegrade selective cerebral perfusion (ASCP)

The concept of antegrade perfusion is an appealing one, since it is definitely more physiologic than any "no flow" or the retrograde perfusion approach. Basically this technique is used in combination with deep or profound hypothermia and perfusion of one or more supraaortic vessels.

ASCP is an older technique than RCP, dating back to the early working of De Bakey.⁴² In 1957, De Bakey and colleagues were the first to apply the technique of selective antegrade cerebral perfusion. He successfully introduced DHCA, and made DHCA the preferred technique for aortic surgery.



First⁴³ revisited the concept of ASCP in 1986, using a simplified CPB circuit, moderate hypothermia and selective antegrade perfusion of the innominate or left carotid artery.

Later using ASCP as an adjunct to DHCA was championed by Bachet⁴⁴ and Kazui et al [45] both groups described delivering cold cerebral perfusion through cannulas placed into both the innominate and left carotid arteries.

C. Hagle⁴⁸ prefer to use special catheter for ASCP – which were originally designed for retrograde cardioplegia (15 Fr, Medtronic, Minneapolis, MN, USA) and introduce them during a 3-5 min. Interval of HCA under visual control via the opened aortic arch into the innominate and left carotid arteries. After meticulous de-airing, perfusion is started with a flow rate of 10 ml/kg/min and is adjusted to maintain the pressure in the right radial artery between 40-60 mmHg. If backflow via the left subclavian artery compromises the surgical field, the subclavian artery is occluded with a Fogarty catheter. This technique offers in their opinion, a relatively uncompromised surgical field, avoids clamp injuries of the arteries and minimizes the risk of microembolic events. The continuous observation of pump flow, pressure and oxygen saturation allows the anesthesiologist to treat the consequences of vagaries of vasomotor tone which frequently occur during SCP.

Griepp and associates⁴⁹ found Under profound HCA, Griepp creates an Island including all three head vessels and attaches the graft to this island. An arterial inflow cannula is now inserted, the distal end of the graft clamped and flow initiated. Usually this procedure takes 10 min of HCA, but allows completely resection of all diseased tissue. One advantage is that this technique can easily be combined with right axillary cannulation, which is now routinely used in many aortic centers.

DiEusanio and coworkers⁵¹, Included 413 patients who were operated on the thoracic aorta using selective ASCP, they demonstrate that even cerebral perfusion time of more than 90 min were not associated with a higher incidence of neurological complications, urgent status and a recent history of central neurological events were important risk factors for outcome.

Okita and coworkers⁵² compared two groups of patients, who underwent total arch replacement with deep DHCA, one with adjunctive RCP, and other with ASCP. Despite the fact that the duration of the operation, total bypass time, and aortic cross-clamp time as well as "cerebral protection time's were significantly longer in the HCA+ASCP group, the incidence of transient brain dysfunction was significantly higher in the DHCA+RCP group.

Harrington.⁵⁴ They found that adjunctive use of ASCP maintained pre DHCA jugular venous saturation and cerebral oxygen extraction (COE) in patients undergoing aortic surgery.

Karadeniz⁵⁸ used transcranial Doppler ultrasonography to demonstrate that unilateral ASCP through the right axillary artery can provide adequate perfusion of both the right and left cerebral hemispheres in patients undergoing DHCA.

Site of cannulation for cardiopulmonary bypass (CPB) and by perfusion technique

Normally the preferred site of cannulation for CPB is usually in the ascending aorta, but this sometimes poses unacceptable risk. When the ascending aorta is unsuitable for cannulation the femoral artery is the most common alternative. The femoral arterial cannulation may be (a) Femoral artery and bicaval venous or caval venous cannulation (Fig.a,b,c). (b)Femoro-femoral arterio-venous cannulation (Fig-b,c).





Fig 1 (a) Showing intraoperative femoral artery and caval cannulation technique for RCP





Fig 1 (b) Showing perfusion circuit setup for RCP during DHCA with use of femoral artery and bicaval cannulation.Part A:-Set up of circuit for femoral arterial and bicaval venous CPB. Part B:-Circuit for retrograde cerebral perfusion.



Fig: Showing Femoro Femora Arterio Venous Cannulation

Fig 1 (c) Showing circuit for RCP with DHCA using femoro femoral arterio venous cannulation during CPB. Part A:-Circuit set up for femoro femoral arterio venous CPB. Part B:-Circuit for retrograde cerebral perfusion.



But retrograde flow in severely atherosclerotic and diseased aorta poses major risks, including dislodgement of plaques and aortic dissection, both of which may lead to cerebral as well as peripheral injury.61-63 Cannulation of the axillary artery has become increasingly widespread. Axillary artery cannulation preserves antegrade flow in the descending aorta while eliminating some of the risks associated with direct cannulation of the ascending aorta. It lowers the potential for embolization into right-sided cerebral vessels by perfusing them with flow which has not transversed the aortic arch, and avoiding the "sandblast" effect of turbulent flow from a catheter tip close to atherosclerotic lesions in the ascending aorta or aortic arch and thus also reduces the risk of embolization into the systemic cerebral vessels.

Arterial inflow through the axillary artery increases the case for using selective cerebral perfusion during the aortic arch repair, which allows the surgeon to construct open proximal and distal anastomosis while the lower body is kept hypothermic during circulatory arrest.

Direct axillary artery cannulation was first described by Villard and co-workers in 1976, but was subsequently only rarely utilized until the Cleveland clinic group published a report with the results in 35 patients.⁶⁴⁻⁶⁵



Fig 2: Showing the technique of unilateral antegrade selective cerebral perfusion through axillary artery and with the main limb of the trifurcated graft clamped, antegrade selective cerebral perfusion is initiated through the axillary artery during replacement of aortic arch.





Fig 3: Showing the diagram of technique for providing antegrade cerebral perfusion during CPB. Separate cannulas are introduced into the innominate artery and the left common carotid artery. A separate arterial pump head can be used to provide cerebral perfusion



By technique of right axillary cannulation. There are two options for ASCP. First one is unilateral antegrade selective cerebral perfusion (UASCP) and second in bilateral antegrade selective cerebral perfusion (Right axillary artery plus left carotid artery) (BASCP) (Fig. 4).

Unilateral antegrade selective cerebral perfusion (UASCP) through axillary artery has been used by several groups with excellent clinical results. During UASCP the left hemisphere blood supply is provided not only by intracranial collateral circulation ("Circle of Willis") but also from an extra cranial vascular bed mostly dependent on the external carotid arteries66-67. The risk of hypoperfusion via UASCP can be minimized using pre-operative magnetic resonance angiography(MRA) assessment. Intra-operative cranial Doppler study and assessment of back flow through the left common carotid artery and left subclavian artery during surgery.

Bilateral antegrade selective cerebral perfusion (BASCP):

Alessandro Mazzola first described the technique of BASCP.68 cerebral protection during DHCA was obtained by combining right carotid perfusion through the axillary artery with selective perfusion of the left common carotid artery. Surgical exposure of the axillary artery is easy to perform, and if the operative field and the patient are routinely prepared for this procedure, it is as rapidly performed as femoral exposure.

Unlike the femoral vessels, the axillary artery benefit from rich collateral flow from thyrocervical trunk to the suprascapular and transverse cervical arteries, avoiding the risk of upper extremity ischemia during total distal occlusion.69

- The axillary artery is generally free from atherosclerosis even in the presence of several aorto-iliac diseases.
- In the surgery of aortic dissection. It provides antegrade perfusion of the true lumen when the circulation is resumed after distal anastomosis, avoiding the need of graft cannulation.
- Antegrade cerebral perfusion is never stopped.
- Bihemispheric perfusion is assured having only one cannulae in the operating field.
- The risk of air embolism during the carotid cannulation is reduced because of the back flow through the left carotid artery.
- Dearing at the end of the arch procedure is very easy to perform. BASCP can also be established by another method.

After opening the aortic arch wall, retrograde coronary sinus perfusion cannulae may be inserted into the brachiocephalic and left common carotid artery, through the aortic lumen and bilateral ASCP will be established (Fig. 3). The left subclavian artery can be clamped.

AN INEXPENSIVE TECHNIQUE OF BILATERAL SELECTIVE ANTE GRADE CEREBRAL PERFUSION70 (Perfusion Strategy) :-

In this technique, an arterial line is placed in the right radial artery for monitoring of the arterial pressure. The 3/8 inch tubing of the arterial line is bifurcated by using a 3/8 inch 'Y' connector and 3/8 inch extra tubing (Fig. 5a). The line A is used either for ascending aorta or femoral arterial cannulation. Line B is bifurcated again in a similar fashion. Two cuffed endotracheal tubes, One No. 6 (internal diameters6 mm, and external diameters8.2 mm) and another No. 5.5 (internal diameters5.5 mm, and external diameters7.6mm) are connected to both the divisions of line B using two 3/8-1/4 inch straight connectors (Fig.5b). Local carbon-dioxide insufflations is continued at 3L/Min in surgical field to minimize the risk of air embolism. The arch vessels are looped but are not snared or clamped. Once circulatory arrest is achieved and



the aortic arch is opened, line A is clamped and line B is kept open. The arterial pump is started at a rate of approximately 100ml/min. No. 6 endotracheal tube is inserted in the innominate artery and No. 5.5 endotracheal tube in the left common carotid artery (LCCA), and their balloons are inflated. Arterial flow is increased to 10 ml/kg of body weight, and increased further, if required, to maintain the right radial arterial pressure of around 50 mmHg. The left subclavian artery is cross-clamped during the procedure.

When the arch reconstruction is nearing completion, pump flow is reduced, line A is opened and line B is clamped. The balloons are deflated and the endotracheal tubes are removed with the patient in Trendeleberg position. Once the anastomosis is complete, aortic cross-clamp is reapplied on the graft just proximal to the origin of arch vessels and full cardiopulmonary bypass is re-established.



Fig; 5a.-The 3/8 inch tubing of the arterial line is bifurcating by using 3/8 inch 'Y' connector and 3/8 inch extra tubing.The line A is used either for ascending aortic or femoral arterial cannulation. Line B is bifurcated again in a similar fashion.





Fig 5(b):-Line B is bifurcated again in a similar fashion. Two cuffed endotracheal tubes, one No.6 and another No.5.5 are connected to both the divisions of line B using two 3/8-1/4 inch straight perfusion connectors.

ANALTERNATIVE METHOD FOR RETROGRADE CEREBRAL PERFUSION:

Simplified technique for retrograde cerebral perfusion during repair of distal aortic arch and proximal descending thoracic aorta71 –The authers used a modified extracorporeal circuit to deliver retrograde cerebral perfusion (RCP) through left internal jugular vein (LIJV). Fig 6 (a)



Fig 6(a) once the left internal jugular vein was dissected, the left upper limb was shifted toward the head. The final position of the patient, the cardiopulmonary bypass circuit, and the retrograde cerebral perfusion (RCP) circuit are shown.





Fig 6 (b) Showing modified extracorporeal circuit to deliver retrograde cerebral perfusion (RCP) (BCD = Blood Cardioplegia System).



Material & methods

Between August 2008 and November 2009, a total of 10 patients with aneurysm/dissection of ascending and aortic arch underwent ascending aorta/arch replacement. Surgery performed under DHCA with either ASCP or RCP. Seven patients (Group-A) underwent ASCP and three patients (Group-R) underwent RCP.

Patients Profile

Adult patients of either gender with aneurysm or dissection of aorta involving ascending aorta or arch of aorta were studied. Patients with associated diseases such as diabetes mellitus, hypertension and atherosclerosis were not excluded. Electively posted patients are considered for the study.

Surgical Technique for ASCP

Bilateral, ASCP for cerebral protection during ascending aortic/arch of aorta surgery. The right and left radial artery were cannulated for pressure monitoring. A skin incision (approximately 6 cm long) was made under the clavicle. The pectoralis major was divided and when necessary also the pectoralis minor. The axillary vein was retracted. The axillary artery was identified and carefully exposed paying attention to the brachial plexus that lies laterally and anterior to it. After heparin administration, tube graft (8 or 9 mm) was anastomosed end to side to the right axillary artery. Atriocaval (Bicaval) cannulation was used for venous return. CPB was started. Before the DHCA, systemic temperature was lowered to 18°C. The innominate artery was clamped and pump flow was reduced to 10 ml/kg/min. The aorta was opened and the left carotid artery was identified from the inside of the lumen of aortic arch and it was selectively cannulated with a retrograde cardioplegia cannula and connected to a separate roller pump (from blood cardioplegia pump (Fig- 4) and cerebral blood flow was maintained at 10 ml/kg/min with a right radial artery pressure between 40-70 mmHg. The left subclavian artery was occluded from within the aortic lumen with Foley's catheter.



Fig 4(a):- Showing simplified technique for bilateral antegrade selective cerebral perfusion (BASP) through right axillary artery and left common carotid artery.





Fig 4b:-Showing CPB circuit for ASCP through right axillary artery cannulation.



For RCP

For RCP we used a standard CPB circuit, median sternotomy was done. After systemic heparinization the femoral artery and femoral vein (Femoro-femoral arterio-venous) was cannulated to establish CPB. A single venous cannula/cardioplegia cannula was inserted into SVC and attached to a separate roller pump (Fig- 7). Total circulatory arrest was achieved by the lowering the patient temperature at 18 degree centigrade and aortic arch was opened with no clamping and RCP was started with a flow of 500 to 600 ml/min. with pressure limit of 25mmHg permitting oxygenated blood flow into the SVC and upward into the sub-clavian and jugular venous system. Deoxygenated blood was return through the brachiocephalic arteries within the aortic arch and can be collected back into the bypass circuit via cardiotomy suction positioned within the open aortic arch.



Path : SVC-----> Immeminate Vein -----> Juglar Vein -----> Corebral Vein ----> Capillaries ----> Corebral Artery ----> Arch of Aorta

Fig- 7 Complete Circuit



Result

The extent of ascending / aortic arch replacement and associated procedure are listed in table 1.

Table 1: Profiles of patients with retrograde cerebral perfusion (Group R) and with antegrade selective cerebral perfusion (Group A) (

Type of surgery	Group-R Total no. patient (n=3)	Group-A Total no. patient (n=7)
Bentall + Arch replacement	0	2
Arch of aortic aneurysm repair + CABG	0	1
Arch of aorta replacement + CABG (Elephant trunk technique)	0	1
Ascending aorta + hemiarch replacement (26 mm Dacron) (30 mm Dacron)	2	0
Ascending aorta + total arch replacement	1	0
Arch + descending aorta replacement	0	2
Total arch replacement	0	1

During this study nine patients, 2 from group R and 7 from Group A were discharged from the hospital without any major complications and one patient from group R was died, not due to perfusion technique but due to surgical complications. All the patients from both groups after operation regained consciousness in 12 to 18 hours and were extubated after 22 to 48 hours. All patients were discharged from hospital after 7 to 13 days. No significant difference was observed between both groups regarding neurological outcome. Table 2 shows the operative data of all the patients.



Table 2:Comparison in operative data between group R and Group A

Operative variable	Group R (n=3) (mean) ± SD	Group A (n=7) (mean) ± SD
Cerebral perfusion time (in minute)(Range)	67.6 ± 4 (65-70 min)	47.4 + 18 (38-65 min)
Total aortic X. Clamp time(min)(Range)	193 (170-207 min)	100.42 (60-174 min)
Total cardiopulmonary bypass time (min) (Range)	302.66 + 8 (278-320 min)	213.71 + 16 (197-222 min)
Minimum nasopharyngeal temperature (°C) (Range)	18° + 1°C	18° + 1°C
Hospital stay (days) (Range)	10.0 (5-13)	8.7 (5-11)

Only hospital stay was more in group R compare to group A. We believe that ASCP by axillary artery cannulation over RCP offers several advantages:-

- 1. The axillary artery is generally free from atherosclerosis even in the presence of severe aortoiliac disease.
- 2. In the surgery of aortic dissection, it provides antegrade perfusion of the true lumen when the circulation resumed after distal anastomsis avoiding the need for graft cannulation.
- 3. It provides antegrade perfusion of the true lumen in aortic dissection.
- 4. Antegrade cerebral perfusion is never interrupted and more physiological than retrograde.
- 5. Bihemisapheric perfusion is having assured only one cannulae in the operating field.
- 6. Dearing at the end of arch procedure is very easy to obtain.

Definitions of neurological complications which we were observed during postoperative:-. Patients were considered to have had permanent neurologic injuries, if they exhibited the presence of new neurological dysfunction after surgical intervention, whether focal injury (stroke) or global (coma) dysfunction or were found to have new focal or multiple brain lesions conformed by means of brain computed tomographic (CT) scanning or magnetic resonance imaging.

Temporary or transient neurological dysfunction (TND), as defined by Ergin and associates²³ indicated the occurrence of postoperative conflusion, agitation, delirium prolonged obtundation, or transient parkinsonism with negative brain CT scans and complete resolution before discharge.



Discussion

Although brain complication remains a rare event after cardiac surgery. It is a major cause of postoperative mortality and morbidity in thoracic aortic surgery. An alarming prevalence $(1\% \text{ to } 83\%)^{72}$ of postoperative neuropsychological dysfunction has been reported after cardiopulmonary bypass. Improvement of methods to assess the postoperative neuropsychiatric status has been achieved recently .However there is no simple method to determine the incidence or severity of brain injury after a cardiac operation. In this study, we performed a comparative study of two different methods of brain protection, deep hypothermic circulatory arrest with RCP or ASCP in aortic arch replacement.

Recent reports indicated that the majority of permanent neurologic injuries were due to strokes resulting from embolic phenomena, and were not directly related to the method of cerebral protection used.

Coselli and LeMaire⁷³ reported that patient who had RCP during DHCA had lower mortality (7.9%) and stroke (2.4%) rate than those who did not undergo DHCA with RCP (early mortality 14.8%, stroke 6.5%) in their 479 patients.

Safe and associates⁷⁴ demonstrated the use of RCP had a protective effect against stroke (3 of 120 patient or 3%) compared with no retrograde cerebral perfusion (4 of 41 patient, or 9%).

Certain limitations existed in evaluating the postoperative result of the neuropsychiatric tests. The main limitation was that the test was net simple enough for recovery patients to answer on the 10th postoperative day. The sickest patients were not able to do the tests, because usually they were intubated, sedated, and on a ventilator in intensive care unit. However, a significant postoperative decline of memory function in patients with transient cerebral dysfunction was demonstrated.

For an operation that requires circulatory arrest. It is necessary to resolve two main problems the choice of arterial inflow for cardiopulmonary bypass and choice of the cerebral protective strategy. For the first, the common femoral artery is the most commonly used site for arterial inflow, but this route cannot be available in all cases because of several ileo-femoral disease and it can be expose to the risk of retrograde atheroembolism from atherosclerotic aorta.⁷⁴ To avoid this problem, we chose axillary artery cannulation for ASCP. In order to guarantee cerebral protection. There are several options –

- 1. Deep hypothermic circulatory arrest offers only about 45 min as a relatively safe period to perform the procedure.
- 2. Retrograde cerebral perfusion has gained popularity in the last decade allowing a longer safe period of circulatory arrest.
- 3. Antegrade selective cerebral perfusion at 22°C temperature has been proven a reliable technique to protect the brain without the drawback of more deep hypothermia.⁴⁹ During this study we were operated 10 patients (Table1) and we used DHCA+RCP and DHCA+ASCP of cerebral protection technique.

We used right axillary cannulation for ASCP. Although in our study the number of patient is limited, so it does not allow any static evaluation. We were not found any significant difference in mortality, morbidity and neurological outcome in two groups. But we believe that axillary artery canulation for ASCP propose easy technique and offer several advantages over other techniques. Advantage of axillary cannulation for ASCP–

- 1. Axillary artery is generally free from atherosclerosis even in the presence of severe aorto-iliac disease.
- 2. In the surgery of aortic dissection, it provides antegrade perfusion of the true lumen when the circulation is resumed after distal anastomosis avoiding the need of graft cannulation.
- 3. Antegrade cerebral perfusion is never stopped.



- 4. Bihemispheric perfusion is assured having only one cannulae in the operating field.
- 5. The risk of air embolism during the carotid cannulation is reduced, because of the back flow through the left carotid artery.
- 6. Dearing at the end of the arch procedure is very easy to obtain.

Conclusion

ASCP is an effective and safe method of brain protection during aortic arch surgery. Our result suggest that axillary artery cannulation for ASCP is successful and may be the optimal technique for reducing perfusion-related morbidity and adverse outcome in operation for acute dissection, atherosclerotic and degenerative aneurismal disease.

Study Limitations

Biostats for all the examinated parametrs were not possible due sample space (n=10). Time approved by Ethics commettee was limited.

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Original Article

Typical temperature rebound post operationin elective cardiacsurgeries



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ABSTRACT

Objective: Hypothermia is an essential component of cardiac surgery requiring hypothermia, circulatory arrest and inadequate cooling of the brain may lead to brain injury. Similarly, brain hyperthermia during the rewarming phase of cardiopulmonary bypass may also lead to neurological injury. Conventional cooling and rewarming of the patient according to the guideline of the temperature. Normothermic, Hypothermic bypass, temperature monitoring sites may change according to the surgery Nasopharyngeal (NP), Rectal(R) Oral (O) temperature for monitoring.

Methods: Patients was randomly divided into two groups A and B. Group A (n=15) patients undergoing hypothermia (28°C) and Group B (n=15) patients undergoing normothermic bypass(35°C) for coronary artery bypass or valve surgery were studied.

Results: Atypical drop is seen in (Group A) hypothermia till (29.17 ± 2.05) which is quite less till (30.53 ± 2.39) in other (Group B) which is normothrmic within a 4-5 Hrs of post surgery.

Conclusions: During normothermia CPB techniques, or hypothermia arterial inflow temperature should be carefully monitored and a nasopharyngeal temperature ceiling of 35° C nasopharyngeal should be a prompt to discontinue rewarming prior to CPB separation. Brain hyperthermia is to be avoided. Perioprative temperature drop in group-A is $4\pm5^{\circ}$ C in group-B it is $3\pm4^{\circ}$ C.

Keywords:-Oral, Nasopharyngeal, Rectal


Introduction

Temperature management during cardiopulmonary bypass (CPB) continues to be an important issue. Sub-optimal temperature management may contribute to the development of adverse outcomes, in particular, neurological injury. As direct brain temperature measurement is not possible other than in some neurological procedures, surrogate temperature monitoring sites are used to estimate the brain temperature.^{1,2} The most commonly monitored sites include nasopharynx (NP), oesophageal (O), bladder (B) in addition to arterial inflow (AI) and venous return (VR). Other sites include tympanic membrane, rectum(R)and skin. Various studies have shown that these standard sites may not reflect the true brain temperature.^{3,4}We sought to compare the routinely monitored temperature sites to the brain temperature.

Major neurological event stroke after cardiac surgery is not very common (1.5% to 7.5%), occurrence of neurocognitive dysfunction after CPB Incidence varies from 30 to 80%. Such dysfunction may persist for up to five years after surgery.⁵ management of temperature during CPB is one of the simplest interventions that could affect neurological outcome after CPB. Therapeutic hypothermia wasused to improve neurological outcomes in patients with severe head injury⁴, resuscitation from cardio-respiratory arrest with mild hypothermia improving both survival and neurological outcome.⁶ Hyperthermia delays neuronal metabolic recovery and increases excitotoxic neurotransmitter release, which are as glutamate, oxygen free radical production, intra-cellular acidosis, and blood brain barrier permeability. Hyperthermia also affects protein kinase activity and destabilizes the cytoskeleton.⁷ Hyperthermia worsens the prognosis of patients with acute stroke by increasing the infarct size and mortality. The site of temperature monitoring is also important.⁸

Class-I Recommendations¹⁷

a) The oxygenator arterial outlet blood temperature is recommended to be utilized as a surrogate for cerebral temperature measurement during CPB. (Class I, Level C)

b) To monitor cerebral perfusate temperature during warming, it should be assumed that the oxygenator arterial outlet blood temperature under-estimates cerebral perfusate temperature. (Class I, Level C)

c) Surgical teams should limit arterial outlet blood temperature to <37°C to avoid cerebral hyperthermia.(Class 1, Level C)

d) Temperature gradients between the arterial outlet and venous inflow on the oxygenator during CPB cooling should not exceed 10°C to avoid generation of gaseous emboli. (Class 1, Level C)

e) Temperature gradients between the arterial outlet and venous inflow on the oxygenator during CPB rewarming should not exceed 10°C to avoid outgassing when blood is returned to the patient. (Class 1, Level C)

Class-IIa Recommendations17

a) Pulmonary artery or nasopharyngeal temperature recording is reasonable for weaning and immediate post-bypass temperature measurement. (Class-IIa, Level C)

b) Rewarming when arterial blood outlet temperature \geq 30°C:

i. To achieve the desired temperature for separation from bypass, it is reasonable to maintain a temperature gradient between arterial outlet temperature and the venous inflow of $\leq 4^{\circ}$ C. (Class-IIa, Level B)

ii. To achieve the desired temperature for separation from bypass, it is reasonable to maintain a rewarming rate $\leq 0.5^{\circ}$ C/min. (Class IIa, Level B)



c) Rewarming when arterial blood outlet temperature $<30^{\circ}$ C: To achieve the desired temperature for separation from bypass, it is reasonable to maintain a maximal gradient of 10° C between arterial outlet temperature and venous inflow. (Class IIa, Level C)

Theses guidelines are followed in rewarming.

Methodology

We had conducted this study to compare the effect of hypothermia and normothermia. This study was performed on 30 adults of either sex in the range of 25 to 70yrs of age with weight more than 30kg undergoing cardiac surgery. the patients were randomly divided into two Groups A and B. Group A (n=15) patients undergoing hypothermia (28°C) and Group B (n=15) patients undergoing normothermic bypass(35°C) for coronary artery bypass or valve surgery were studied. This study was performed from February 10, 2019 to june 20, 2019. In seven months this study is conducted in the Department of CTVS, AIIMS, New Delhi in respective Operation Theaters. Informed consent was obtained from all participating patients.

Peripheral temperature monitoring sites

All calibrated temperature probes were used to measure the NP, R, B and OS temperatures. The nasopharyngeal probe was placed 5 cm from the external nares and the bladder temperature was measured using a urinary catheter temperature probe. The arterial and venous temperatures were measured directly from the CPB circuit. All the temperature probes were pre-calibrated. All patients underwent neurological examination 24-48 h post-procedure.

Normothermic bypass patients underwent coronary artery bypass surgery or valve surgery using a similar bypass circuit. Normothermia was defined as maintaining a rectal (R) temperature of 35 - 37 °C. Anesthetic induction and maintenance techniques were identical.

Statistics

Collected data were transferred onto a computer spread-sheet and analyzed usingStatistical Package for the Social Sciences SPSS by (IBM version 11.5) software with t-test and Two-sample Wilcoxon, rank-sum (Mann-Whitney) test Continuous variables with normally distributed data were compared with analysis of variance. If there are significant differences between groups, the other comparisons between groups (Group A & B) were performed by the q-test. The p value of less than 0.05 is considered statistically significant. All data are presented as mean \pm standard deviation [SD]

Results

There were no complications in temperature probe insertion and nor patients developed a neurological deficit. Bypass time and clamp time are significant in preoperative data. Duration of ventilation was also significant perioperatively.



	Group A	Group B	P- value
Age (yrs)	39.5±15.72	36.63±13.52	0.45
Ht (cms)	159.7±9.47	158.3±10.25	0.58
Wt (kgs)	53.45±11.33	55.58±9.34	0.43
BSA (m2)	1.53±0.19	1.55±0.16	0.61
Bypass Time	103.5(48-226)	63(27-180)	0.001
Clamp Time	63(27-180)	43(22-95)	0.003
Blood Priming	350(100-1200)	400(50-1000)	0.85
Volume Removal	600(200-900)	600(100-900)	0.46

Table: Showing preoperative demographic data

*mean \pm standard deviation values are taken for the analysis

*mean (lower- higher) deviation values are taken for the analysis

*p>0.05 means Non significant difference

Table: Showing	difference in	temperature	with res	pect to time	e
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Temperature	Group A	P value (independent)	Group B	P value (independent)	95% C. I.	<i>P</i> - value
1	35.62±0.82	-	35.86±0.58	-	(-0.12,0.59)	0.2
2	28.13±1.98	0.06	32.69±1.71	0.001	(0.62,2.49)	0.07
3	34.77±1.34	0.38	34.83±1.36	0.001	(-23.78,7.90)	0.32
4	29.1 7±2.05	0.001	30.53±2.39	0.001	(0.46,1.78)	0.24
5	32.95±1.83	0.48	33.23±1.82	0.001	(-27.87,9.63)	0.34
6	33.14±1.42	0.001	33.17±1.66	0.001	(-0.74,0.80)	0.94
7	33.19±1.86	0.001	33.01±1.58	0.001	(-1.04,0.69)	0.69

(1-pre-operation, 2-after cooling, 3-post bypass 4-4hrrs perioprative 5-6hrs perioprative, 6-12hrs perioprative 7-24hrs perioprative)

*mean \pm standard deviation values are taken for the analysis

*p>0.05 means Non significant difference



	Group A	Group B	P-value
Duration of Ventilation (hrs)	8.5(2 -20)	6(3 - 24)	0.001
Addition of Blood	2(1 -4)	2(1 - 10)	0.22
Platelets	2(1 -6)	2(1 - 4)	0.54
Cryo	2(1 -3)	1(1 - 1)	0.34
FFP	2(1 -6)	2(1 - 9)	0.5
Icu Stay Hrs	37(12 -144)	36(18 -72)	0.21

Table: Showing Perioperative data

*mean (lower- higher) deviation values are taken for the analysis

*p>0.05 means Non significant difference

Discussion

hypothermia has been an important neuroprotective strategy throughout the history of cardiac surgery. Bigelow et al demonstrated that oxygen consumption falls in a linear fashion with body temperature and that ischaemic tolerance is extended by cooling.6,9 hypothermia may afford neuroprotection by a variety of complex mechanisms including decreased excitatory transmitter release, reduced ion influx and reduced vascular permeability.10 Even a 2°C reduction from normothermia may have beneficial effects.7 During core-cooling on CPB, brain cooling may not be

homogenous. Thus, conventional temperature monitoring sites such as NP temperature may not reflect true brain temperature.7,11 Normothermic bypass has been shown to have various systemic advantages.12,13 There have also been reports of increased adverse neurological events.14,15 One possible mechanism for increased brain injury is the potential development of brain hyperthermia during CPB.16 Brain hyperthermia may not be apparent if conventional temperature monitoring sites are used as these may be inaccurate and may therefore underestimate true brain temperature. there is a necessary reliance on indirect peripheral temperature measurements as guide to brain temperature and the most commonly used site is the nasopharynx. Crowder et al.4 have shown that the core brain temperature is reflected by the Jugular Bulb (JB) temperature. Little is known about intra-cerebral shunts and how they change during deep hypothermia and normothermic CPB.

Conclusion

The duration of rewarming and control of thermal gradients may is much important. Slow rewarming to prevent rapid heterogeneous changes in brain temperature may beneficial. During warm CPB techniques, arterial inflow temperature should be carefully monitored and a nasopharyngeal temperature ceiling of 35°C should be a prompt to discontinue rewarming prior to CPB separation if brain hyperthermia is to be avoided.

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Conflict of interest

No conflict of interest

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Case report

ECMO as a Bridge to Heart Transplant in a single ventricle physiology patient – a CASE REPOR



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OBJECTIVE:

To present a case report on a single ventricle physiology patient who was supported on ECMO as a bridge to heart transplant and managed effectively later underwent successful transplant.

CASE DETAILS IN BRIEF:

A 17 year old patient with a single ventricle physiology (Tricuspid Atresia) was admitted with adverse signs and symptoms of congestive heart failure. He arrested in the CCU and was put on emergency ECMO as ECPR. After the ECPR his CT revealed sub acute infarct in the bilateral frontal lobes and left parietal lobe. But he showed signs of neurological recovery after few days. He was stabilized on ECMO with a LV vent in place and listed for emergent heart transplant. After one week of ECMO he received a suitable donor heart for transplant. He underwent successful heart transplantation and did not require ECMO in the post operative period.

DISCUSSION:

The successful resuscitation of ECPR, cannulation strategy, placement on ECMO and the management of ECMO will be discussed in the presentation. The post transplant management and his successful rehabilitation to recovery will be discussed.

CONCLUSION:

ECMO/ ECPR as a bridge to transplant played a significant role in the recovery of this patient.

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) has served for more than 2 decades as the standard care for mechanical support as a bridge to heart transplantation. Heart transplantation is currently considered the best treatment alternative for patients with advanced heart failure that is unresponsive to medical therapy1.Due to donor shortages and the current allocation policies, time on the waitlist for a donor heart can be prolonged with an increasing number of patients requiring left ventricular assist devices (LVADs) or Extracorporeal life support (ECLS) as a bridge to heart transplant. Increased experience with ECLS as a mode of cardiac support has expanded its use to diverse patient populations including patients requiring ECLS as a bridge to heart transplantation, and patients who require post transplant support for primary graft dysfunction (PGD). Patients with congenital or acquired heart defects who fail to separate from cardiopulmonary bypass



are increasingly being supported by ECLS as a bridge to recovery, bridge to a definitive form of mechanical support, or bridge to transplantation (BTT). Post transplant survival was better in patients who did not require mechanical cardiac support or who were bridged with VADs as compared with patients who were bridged to transplantation with ECLS.

CASE REPORT

A 17yr old boy admitted due to recurrent atrial arrhythmias with vitals of blood pressure 100/60 mm of Hg, heart rate of 105 bpm, saturation of 80% and serum potassium of 3.5 mmol/l. Echocardiography showed the presence of Levocardia with Ebstein's anomaly, severe tricuspid regurgitation, small secundum ASD, bi-directional shunt and dilated left ventricle with severe dysfunction. Patient was treated with antiarrhythmic drugs. Later he had peripheral edema, pyrexia, dyspnea NYHA IV. Due to the poor ventricular dysfunction he was unsuitable for any surgical correction. Over a period of time in the CCU (Critical Care Unit) the patient had multiple episode of bradycardia followed by cardiac arrest and reverted with CPR. Due to high end inotropic support and with multiorgan dysfunction, has been established as a bridge to recovery or bridge to decision.

ECMO INITIATION



Central VA ECMO initiated due to cardiac arrest. ECMO circuit consist of Maquet Rotaflow, Maquet PLS oxygenator with integrated heat exchanger, an air oxygen blender (sechrist industries, anaheim, CA USA) is used to ventilate membrane oxygenator. Heparin administrated with 2mg/kg and acheived ACT 245 sec.. Central VA-ECMO was established by utilizing 24fr EZ glide aortic cannulae with 32fr straight DLP for right atrium. Acheived full flows of 4.2 LPM with 2900 RPM by inserting an additional cannula in the LV Apex. The LV Apex cannula position by Chest X Ray is shown in the picture (Figure: 1).

Figure 1

Metabolic acidosis corrected and kept with normal limits with saturation of 100%. All three cannulae were tunnelled out. Hemostasis done and chest closed.

ECMO MANAGMENT

VA ECMO provides circulatory, oxygenation, and ventilatory support for the purpose of aiding with end-organ perfusion as well as to, potentially, provide myocardial rest to oxygenate any blood delivered to the lungs by the patient's heart to minimize atelectasis and lung injury, low tidal volume mechanical ventilation with positive end expiratory pressure applied. ANTIBIOTIC Zosyn 4.5gm three times in a day, teicoplanin and fluconazole 20mg one time a day given. ECMO management, including left ventricular (LV) venting, focus on achieving myocardial recovery and preventing pulmonary damage. ECMO flow maintained 70ml/kg with a mean arterial pressure > 60 mm Hg monitored with an arterial line, placed in the right arm. Second hourly ABG done to monitor electrolytes and gases. Venous saturation (Svo2) and lactate were measured frequently to assess the adequacy of perfusion. Inotropic support was withdrawn to decrease myocardial oxygen demand and facilitate myocardial recovery.LV decompression is a fundamental component of VA-ECMO management to promote myocardial recovery, prevent lung injury related to elevated pulmonary venous pressures, avoid stasis within the LV by decompressing the heart.



500IU (7IU/kg) Heparin started once the ACT was down to 220sec on ECMO. ACT monitored every second hourly and APTT on 6th hourly to titrate heparin infusion to maintain adequate anticoagulation. Target ACT of 160-180sec, APTT ratio 1.60-1.80, Target Hct of 30-35%, platelets >100,000 to minimize bleeding, plasma fibrinogen >1.5g/L were maintained. Blood investigation total blood count, KFT, LFT, LDH, coagulation profile, plasma free Hb fibrinogen were monitored periodically and were managed accordingly. Day four on ECMO, TEG showed MA angle of < 40 which was corrected by platelet transfusion. Patient's creatinine was 1.4mg/dL on first day of admission gradually increased to 2.5mg/dL. Due to persistent hyperkalemia, acidosis and raised creatinine 100ml/hr CRRT was started to through neck dialysis sheath. Pre pump (< - 40mmHg), pre and post membrane pressures (Delta P 25mmHg) were within the desirable range. Hourly observed for clots near connectors.

Neurological status on third day of ecmo, patient was not responding to command. Immediately mobilised to CT scan. CT showed multiple areas of hypodensities involving bilateral frontal lobes and left parietal lobe with effacement of overlying sulci, likely representing subacute infarcts. Fortunately he recovered completely without any neurological deficits. On 5th day of ECMO Patient was weaned from ventilator on central VA ECMO.

Early mobilization and therapeutic exercises reduces delirium and days on mechanical ventilation, shorten ICU and hospital stay, improve physical function, and reduce healthcare costs2, 3.Our ECMO patients are evaluated daily to assess hemodynamic and respiratory stability and suitability for mobilization and exercise program. Assessment includes cardiovascular parameters, ECMO circuit, APTT and arterial blood gas results and targets, muscle relaxation use, medical and nursing plan for the day, recent chest X-ray. Patient safety is a primary goal and to achieve this, the multidisciplinary ECMO team pays due attention to intravenous lines, ECMO cannulas, and monitoring devices in place. Maintenance of adequate oxygenation and hemodynamic stability has to be assured throughout mobilization and rehabilitation therapy.

HEART TRANSPLANTATION

On 7th day of ECMO we tried to wean from ECMO but we were unable to wean due to RV failure and hypoxia. Hence patient listed for emergency transplantation. On 8th day, he was fortunate enough to get a compatible heart. The donor was 50 years old due to hypoxic ischemic encephalopathy. The recipient was shifted to OT with ECMO (183hours). We used the same Aortic cannula but went with Bicaval cannulation for the CPB. The ECMO circuit which was used was kept aside in a sterile manner and was looped to recirculate in order to keep the circuit patent. The CPB time was 240 mins and Clamp time was 74 mins. We tried weaning but at 50 % flow the new heart started distending. Intra op TEE: BV Dysfunction, TAPSE 9mm, Moderate Inotropic support.

ECMOAFTER TRANSPLANT

Due to hemodynamic instability ECMO was reinitiated with RA & Aorta (Same Circuit), Inotropes were stopped. PGD is a life-threatening complication after heart transplantation. Its incidence varies between 3–30%, depending on the series, and PGD accounts for 40–50% of early mortality seen after heart transplant according to studies using the International Society of Heart and Lung Transplantation (ISHLT) registry1. Donor age, organ ischemic time, mechanical circulatory support [including right ventricular assist devices (RVADs)] prior to transplant, and congenital etiology in the recipient seem to be associated with a higher rate of PGD. Recently, a consensus statement, which attempted to better define PGD in heart transplantation, classified severe PGD as a need for mechanical circulatory support (other than an intra-aortic balloon pump) to maintain adequate end-organ perfusion following the procedure4, Heart recovered vigorously after 154min on ECMO. ECMO weaned off gradually and decannulated with moderate support. Hemostasis secured & Chest closed.



POST OPERATIVE PERIOD



CRRT was continued to maintain zero balance. Tracheostomy was done on 7th POD. Regular Chest Physiotherapy and Post surgical rehabilitation was provided meticulously. He was on regular Immunosuppresants and the patient was discharged after 45 Days (preop + postop). Post transplantation chest X-ray (Figure: 2)

Figure 2

DISCUSSION

Central VA ECMO is effective in this scenario because the patient was going into cardiogenic shock and was deteriorating due to recurrent ventricular arrhythmias. By initiating Central VA ECMO at the right time without wasting golden hours for gaining peripheral access was the right decision that helped to revive him and make him a candidate for transplant. VA ECMO with LV vent in single ventricle physiology unloads effectively, prevents distension and decrease myocardial oxygen demand. Required pump flow was 4.2LPM. Since it was a single ventricle physiology, the right ventricle was rudimentary and most of the blood drains into left ventricle and some extent into right atrium. We were able to achieve only 3LPM with RA and Aorta cannulation and the single ventricle was still distended. Hence left ventricle apex was cannulated with 28fr Rt DLP (Pacifico cannulae) in order to decompress the left ventricle. 1.3-1.5 LPM drained from left ventricular apex, measured by a Centrimag ultrasonic flow sensor (Figure: 3).



Figure 3

VA ECMO with Venting helped the patient to maintain good tissue perfusion by providing full flows.

As a candidate of bridge to transplant by offering ECMO support at the right time we were able to provide good end organ perfusion and avoid multi organ dysfunction and were able to help this patient to survive longer. He was fortunate to recover completely from a mild Cerebrovascular accident and got a suitable heart within a short span of

ECMO support. ECMO not only helped preoperatively but also supported post operatively by resting ventricles and to prevent primary graft dysfunction. Impeccable intensive care is recommended for these patients as they are vulnerable for infections due to Immunosuppresants. The collective effort of the doctors, nurses, perfusionists, physiotherapists and support staff helped in the speedy recovery of the patient.

Conclusion:

ECMO as a bridge to transplant or decision is quite effective in saving patient lives while they are waiting for a suitable donor. It provides support and acts as a bridge for the sick heart failure patients who are suffering from cardiogenic shock and helps to survive them better.



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Case report

PERFUSION STRATEGY ADOPTED FOR A CASE OF REDO MVR IN A PREGNANT FEMALE



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Abstract:

Cardiac surgery carried out on Cardio Pulmonary Bypass in a pregnant woman is associated with very poor neonatal outcomes, whereas maternal risk is the same as for any other non pregnant female. The most adverse maternal and fetal outcomes from cardiac surgery during pregnancy are attributed to effects of CPB. Utero-placental hypoperfusion caused due to a number of factors, may translate into low fetal cardiac output, hypoxia and even fetal death, early preoperative optimization of maternal cardiovascular status, adoption of proper perfusion strategy, perioperative fetal monitoring can achieve better maternal and fetal outcomes. It is always safe to avoid surgery during pregnancy, if possible.

Keywords:Pregnancy, uteroplacental perfusion, Redo MVR, CPB, Cardiotocography.

Introduction:

The incidence of heart disease in pregnant women is reported to vary from 1% to 4% with rheumatic mitral valve disease being the most common etiology and accounting for nearly 60% of the cases. [1] Cardiac disease in pregnancy if untreated is responsible for 10%-15% of maternal mortality. [2] Rheumatic Heart Disease is a major cause of death related to pregnancy.

In 1959, the first case was reported when a woman with 6 weeks of gestation underwent Pulmonary Valvotomy and closure of ASD. The mother survived but the fetus aborted three months later. [3] In recent studies the fetal mortality remains at 16-33% .[1] [3] However cardiac surgery in pregnant patients must be limited to cases where medical management fails.

History:

21 year old female a case of Post MVR (10 years back) with stuck prosthetic valve with Primigravida, 22 weeks gestation. DOE class IV, orthopnea, fatiguability, vomiting and palpitations. Ht 154 cm, Wt-49 Kg.

Investigations:

2D Echo:Prosthetic mitral valve leaflets immobile, Sev MS [MVA 0.4 cm²], mean PG of 44 mmHg, Sev PAH, LA dilated.

Hb-10.7, TLC-11,300, platelets - 1.98, Urea - 14.4, sr creatinine - 0.39, Sr bilirubin - 0.33, Sr albumin - 3.27.



Discussion:

Perioperative monitoring included ECG, Invasive blood pressure, Spo2, EtCO2, CVP.

Fetal heart rate and uterine contractions were monitored using Cardiotocography.

After thorough optimization, the patient was taken up for surgery. Before induction a wedge was placed under the right hip so as to obtain a 30 degree pelvic tilt to prevent hypotension caused by the uterus compressing the IVC. The patient was induced with Inj Thiopentone Sodium, Inj Fentanyl and Inj Atracurium. The femoral artery and vein was exposed before incision, in view of Redo MVR. Midline sternotomy was performed, all pericardial adhesions carefully dissected to visualise the underlying cardiac structures. Patient was fully heparinised @4mg/Kg heparin. CPB was initiated, aorta cross clamped and cold Del Nido cardioplegia delivered through antegrade route, cardioplegia effusate was discarded using outside suction through RA. The LA was opened and the stuck prosthetic valve was removed and replaced with mechanical valve. All structures were closed, cross clamped removed, spontaneous return of sinus rhythm was noted and patient was successfully weaned off bypass without any inotropic support. Conventional Ultrafiltration during CPB was done.

Perfusion Strategy:

The main aim of Cardiopulmonary Bypass was to achieve better fetal outcomes and to prevent uteroplacental hypoperfusion. The fetal heart rate and uterine contractions is a useful parameter in maintaining placental blood flow, any significant increase in the uterine contractions or decrease in fetal heart rate is a sign of fetal hypoxia/low flows and needs correction.

Circuit: Standard adult circuit with Arterial filter, Medos Hilite 7000 oxygenator and Blood Cardioplegia Delivery was used.

Priming:

Low hematocrit is known to cause fetal distress, the aim of priming was to keep a minimum perfusate volume to initiate bypass, maintain optimal oncotic pressures and Hct levels above 30%. Total crystalloid prime was used, retrograde priming done to remove volume, 1 unit PRBC and 2 unit FFP was added in the prime. Mannitol was avoided as it crosses the placental barrier.

Pump flows:

During non pulsatile flows, the flows were maintained at a cardiac index of 2.8 so as to sustain adequate fetoplacental gas exchange. After arrest the flows were switched to pulsatile mode.

Gas flows:

In order to achieve better perfusion and gas exchange at the fetoplacental level the FiO2 was kept higher to achieve PO2 of more than 300mmHg, higher maternal PO2 does not effect the fetal organs. The gas flow was kept at 1:1 and titrated according to PCO2 (target of 30-35 mm Hg).

Temperature:

Hypothermia is known to increase the uterine vascular resistance thereby reducing gas exchange at the placenta level, causing uteroplacental hypoperfusion, normothermic bypass was conducted and the maternal temperature maintained between 35 degree celcius to 35.5 degree celcius. The fetal mortality is higher when CPB is conducted with hypothermia, this should be avoided unless extended clamp time is anticipated or DHCA is required.



Perfusion Pressures:

The mean perfusion pressure was maintained above 70 mmHg. During CPB high perfusion pressures, high pump flows and a normal cardiotocography usually presents a clear correlation.

Drugs:

The use of vasoconstrictors was avoided and perfusion pressures maintained with higher flows, however Inj ephedrine does not effect the uterine blood flow and can be used to maintain high pressures. Diuretics were also not a part of our protocol, however Inj Frusemide 5mg was given to promote diuresis because of low urine ouput and was preferred over mannitol.

Result:

The patient was successfully weaned off CPB, perioperatively no significant fetal bradycardia or increase in uterine contractions was observed, all other parameters were within normal limits. Zero day Ultrasound revealed single live fetus with normal cardiac activity, FHR- 153bpm. However significant fetal movements were not observed. On the 4th POD the ultrasound revealed a single live fetus with normal cardiac activity, FHR- 140bpm, but no fetal movements were detected. The patient was discharged on the 6th POD. After one week, during first follow up, the fetus developed subcutaneous edema, ascites suggestive of hydrops fetalis as detected on ultrasound. 26 days later despite all efforts the fetus had to be aborted.

Conclusion:

Maintaining the placental physiology to as normal as possible, avoidance of sudden change in placental blood flow, managing the arterial oxygen tension, hematocrit, temperature and pressures are the key determinants in the management of pregnant patients undergoing cardiac surgery with CPB. Significant changes in the fetal heart rate and uterine contractions should be treated aggressively.

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Case report

ENBLOC HEART AND LUNG TRANSPLANTATION - an institutional experience.



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Introduction:

Enbloc heart and lungtransplantation is the recommended ultimate option of surgery for candidates suffering from irreversible end stage heart and lung disease. This major surgery requires a cohesive multidisciplinary teamwork approach to yield a favourable outcome. The role of perfusionist is vital in this complex operation; the perfusionist is an active participant in the preoperative period, intraop and postoperative period. Our Enbloc heart and lung experience - case report highlights the key elements of this surgery from the perfusionist perspective.

Case details:

A 68 year old male patient was suffering from end stage heart and lung disease refractory to medical therapy due to worsened interstitial lung disease and coronary artery disease. His life style was restricted and required heart and lung transplantation at the earliest. He got a suitable donor and successfully underwent Enbloc heart and lung transplantation. The donor was a 24 year old male who was in comatose state due to traumatic brain injury. The donor specific antibody test was performed and the report was negative. Cold custodial and Perfadex Plus was administered to the donor heart and lungs respectively and harvested.

Discussion (Surgery and Perfusion strategies):

The gold standard approach for Enbloc heart and lung transplantation is the median sternotomy. Standard Bicaval and Aortic cannulation was done cardiopulmonary bypass was instituted. The total CPB time was 250 minutes. Cold cycle was 144 minutes and warm cycle was 75 minutes. Continuous zero balanced ultrafiltration was done to eliminate the inflammatory mediators and to keep the Sr.Lactate within the normal limits. The various perfusion strategies involved in Enbloc heart and lung transplantation and the involvement of perfusionists in the management of these patients is discussed in the article.

Conclusion:

Enbloc heart and lung transplantationis the treatment of choice for endstage heart and lung disease. This type of surgery demands a holistic teamwork approach among the multi disciplinary team that helped in the speedy recovery of the patient.

Keywords: Enbloc Heart and Lung transplantation, Donor Specific Antibody, Human Leukocyte Antigen, Organ Preservation, Cold Ischemic Period, Warm Ischemic Period, Primary Graft Dysfunction, ECMO, Immunosuppresants.



Introduction:

Heart-lung transplant is the ultimate option available for patients who suffer with both advanced irreversible heart dysfunction and terminal lung disease. The term ENBLOC refers to the harvest and implant of heart and lungs together rather separately. Here we report a case of successful transplant of both heart and lungs. Heart and lung transplantation is a suitabletreatment for-selected patients with end stage chronic lungdisease (1).

Case Details:

The recipient is an old man with age of 68 years of age suffering from terminal illness of interstitial lung disease and coronary artery disease with severe LV dysfunction. He was on optimal medical therapy and had NYHA Class IV dyspnea on Oxygen Mask support. His body weight was 62 Kg with B Positive blood group.

Donor Details:

The donor was 24 year old comatose patient followed by a Road Traffic Accident. He was weighing 80Kg with O Negative Blood group. The blood serology for HIV, HCV and HBsAg was negative. The oxygen challenge at 100% FiO2 offered a PaO2 of 545mm of Hg. He was on mild support of vasopressors. The donor specific Antibody test was done and it turned to be negative. The Human Leukocyte Antigen Typing between the donor and the recipient was a 3/6 Locus Match. An induction dose of Basiliximab was given to the donor. The use of induction therapy with Basiliximab in Lung Transplant patients reduces the incidence of acute rejection in the first month after transplant, with no differences in positive Broncho Alveolar Lavage (BAL) cultures (2).

Organ preservation:

The gold standard preservation solution for heart is Custodiol HTK solution and for the lungs, Perfadex plus solution. The Custodiol inactivates organ function by withdrawal of extracellular sodium and calcium, together with intense buffering of the extracellular space, prolongs the ischemic period. Perfadex plus is an extracellular, low potassium, dextran-based electrolyte preservation solution for rapid cooling, perfusion and cold static storage of donor lungs – pre-supplemented with calcium ions and THAM. Pulmonary artery flush cooling was achieved by infusing 50 mL/kg 4°C Perfadex solution through a 24F cannula(3).

Organ preservation technique:

Donor organ preservation is one of the key aspects that determines the outcome of the surgery especially in tackling primary graft dysfunction. We cannulated the aorta with a 14 G cardioplegia cannula and the pulmonary artery with an EOPA 24 Fr cannula. A bolus of 500µg prostaglandin was administered in the PA which induced a bradycardia and mild hypotension. The aorta was cross clamped and simultaneously 2 litre custodial solution was given in aorta with help of a pressurized bag from the anesthesia end and 3 litre Perfadex plus was given in the pulmonary artery by gravity. The return solution was sucked out from the nicks made in the left atrium and right atrium. The trachea was clipped using 4'0 Endo GIA Stapler with subtly inflated lungs. The Enbloc was harvested and immersed in 6 litres cold normal saline solution bag. The whole graft along with the 6 litres NS solution is packaged in a sterile bag which is surrounded by additional two more packs with lots of ice slush.



Considerations of Heart and Lung DonorCriteria (4)

Table:1

- ✓ Age <55 years
- ✓ Clear chest X-ray
- ✓ Oxygen Challenge: PaO2 > 100 mm Hg on 40% FiO2; PaO2 > 300 mm Hg on 100%
- ✓ Absence of chest trauma
- ✓ Absence of microbiologic endobronchial organisms
- ✓ Absence of malignancy
- ✓ Absence of purulent secretions or signs of endobronchial aspiration
- ✓ ABO compatibility
- ✓ Size matching
- ✓ No history of chest trauma or cardiac disease
- ✓ Appropriate hemodynamics: MAP>60; CVP 8 to 12 mmHg
- ✓ Inotropic support < $10 \,\mu/\text{kg/min}$ (Dopamine or Dobutamine)
- ✓ Normal ECG/ Normal ECHO
- ✓ Negative serology (HBsAg, HCV and HIV)

Operative strategies:

The approach was through median sternotomy and CPB was instituted after systemic Heparinization and with standard Aortic and Bicaval venous drainage. The patient was cooled to 28°Celcius and cardioplegia was administered after cross clamping the aorta. The heart and lungs were excised and the trachea was excised just below the carina. The vascular bed around the carina was well preserved. Meticulous care was given to preserve the innervation especially the recurrent laryngeal nerve, Vagus nerve and the phrenic nerve. Preservation of the nerves is often more difficult than in isolated heart or lung removal because of the extensive mediastinal dissection required in heart-lung transplantation, but failure to do soresults in profound postoperative respiratory insufficiency, vocal cord paralysis, or gastrointestinal dysfunction (5). The Enbloc is placed inside the chest cavity correctly and anastomosis of the trachea was performed with 4'0 PDS (polydioxanone) continuously for the posterior aspect of membranous tracheal tissue and interruptedly in the anterior aspect of the cartilaginous tissue. The sequence of anastomosis after the trachea were aorta, IVC and the SVC respectively. The lungs are cautiously inflated and ventilated to prevent any occurrence of lobar atelectasis. Bronchoscopy is carried out to check on the tracheal anastomosis ispatent, and the airways are clear of secretions (5). The lungs are ventilated with 21% air and slowly the oxygen was exposed into the new lungs. After effective deairing the aortic cross clamp was removed. Hemostasis was done meticulously during the CPB. After rewarming patient was weaned off from CPB gradually.

Perfusion strategies:

Aortic cannula was 22 Fr EOPA (DLP-Medtronic), 24 Fr and 28Fr Right angled cannula (DLP-Medtronic) for SVC & IVC respectively. Inspire 6 PHISIO Coated oxygenator was used. Pump flows were maintained >2.2 L/min/m2 with MAP > 60mm of Hg. The cold ischemic period and the warm ischemic period were 144 and 75 minutes. Albumin and Tranexamic acid was continuously on flow. Continuous Zero Balanced Ultrafiltration was carried out throughout the



bypass to keep the inflammatory mediators and lactate levels in check. Two units of irradiated red blood cells were used, the hematocrit while coming off was 32%. Total CPB time was 250 minutes.Cell saver was also used to effectively conserve the red blood cells to minimize the transfusion.

Post operative course:

Inhalational nitric oxide is used in the immediate post operative period to counter rise in pulmonary artery crisis. On the 3rd post operative day the right lung was downsized in the basal area as it was crumpled. In the presence of a moderatesize discrepancy, peripheral non-anatomical resections using stapler devices were performed after implantation and full inflation of the lung (6). Chest was closed properly in the 4th post operative day. Periodic bronchoscopies (once in two days) were carried out to let out the bronchial secretions. Total ventilation hours were 124 hours. Regular chest physiotherapy was done. Patient was put on triple regimen of Immunosuppressant's-Tacrolimus, Mycophenolic acid and prednisolone. The Endomyocardial biopsy and the lung biopsy showed no signs of acute rejection. Endo myocardial biopsy for the heart and Transbronchial biopsy for the lungs remains the "gold standard" and is a widely accepted practice for the diagnosis of rejection in heart and lung transplant recipients (7). Total hospital stay was 24 days. The patient is on regular follow up (6 months) and continues the immunosuppressant therapy.

Discussion:

The one of the key factor to success for this case was the selection of suitable donor and appropriate recipient. The donor specific antibody test between the donor and the recipient was negative and the Human Leukocyte Antigen Typing between the donor and the recipient was 3/6 locus match. The successful outcome of solid organ transplantation today is severely impeded by the production of alloantibodies, mainly directed against the protein products of the HLA complex of the organ donor (8).

The impeccable care during organ harvesting and organ protection holds a significant part in determining the outcome of the surgery. The lesser the ischemic time the better the chance of not developing primary graft dysfunction. The cold ischemic period i.e., the time from the organ is given the preservation solution till it is taken out from the cold storage unit and the Warm Ischemic period i.e., the time from the organ is taken out from the cold storage unit till it is reperfused are crucial for these type of surgeries. Long-term graft survival in heart transplantation patients with older donor allografts may improve when Cold Ischemic Time are shorter (9).

Pump flows were maintained >2.2L/min/m2 with mean arterial pressure >60 mm of Hg. The perfusion was optimized to maintain good adequacy of perfusion throughout the run. The serum lactate during the CPB was <4mmol/L. The mixed venous saturation was maintained >70%. Serial ABGs showed no signs of acidosis. Meticulous haemostasis and utmost care to the innervation were some of the salient features of this complex surgery. The need of post-operative ECMO is quite possible in this type of surgery and the ECMO disposables, hardware and the team should be available as a 24/7 back up just in case if the primary graft dysfunction ensues. Christian A. Bermudezet al suggests that Long-term survival of patients with primary graft dysfunction (PGD) requiring ECMO (overall and weaned) was inferior to that of patients who were not on ECMO for PGD (10).

The post operative care is crucially important in these surgeries. Cardio pulmonary rehabilitation is important to cough out the secretions effectively since the cough reflux would be poor in these patients. These subsets of patients are provided with extreme care of aseptic measures while handling them to avoid any infections.

Conclusion:

Enbloc heart and lung transplant is a high profile surgery offered for patients suffering from end stage heart and lung failure patients that requires multiple strategies in pre-operative, intra-operative and post-operative periods. A holistic cohesive teamwork among the multi disciplinary team helped in the speedy recovery of the patient.



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Case report

Modification in cannulation and perfusion techniques for neonatal aortic arch surgery



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INTRODUCTION

Cannulation techniques for neonatal aortic arch surgeries are challenging because of the anatomy of aorta. The size and site of the cannulae are compromised in which we may forced to go for long deep hypothermic circulatory arrest. Here we are discussing modified technique of cannulation which make the surgery easier for both surgeon and perfusionist.

Arterio venous MUF in neonatal arch surgeries may be harmful because the chances of cannula obstruction and cavitation are very high and it may steal the blood from the cardiac output. Veno arterial muf may be good choice for these patient population because of the safty it provides.

CASE REPORT

An 18 day old male kid was diagnosed with severe coartation of aorta, hypoplastic transverse arch and sub pulmonic ventricular septal defect with postrior deviation of conal septum. Decision was taken for surgery (aortic arch repair+vsd closure) after obtaining the requisite consent from the patients parents.

Patient details

Weight 2.2 kg

Height 45 cm

BSA.17m

Hemoglobin 12.5 gm/dl

Surgical strategy involved single stage repair of aortic arch and vsd closure. The cannulation modified to innominate artery through a gortex graft for the convenience of arch repair. Cardioplegia delivery through aortic cannula was planned to avoid additional incision in aorta. Arterio venous MUF was ruled out owing to the chance of cerebral steal due to innominate cannulation, so it was decided to perform veno arterial MUF.



PERFUSION CIRCUIT

The perfusion circuit was assembled with Maquet quadrox 10000 oxygenator and neonatal custom pack. The hemofilter circuit was modified for arterio - venous modified ultra filtration and cardioplegia delivery.

The main circuit was assembled and the MUF circuit kept completely seperated. The inflow to the muf pump was taken from through 150 cm extension with 3way connected to 1/4 * 1/4 luer lock connector in the venous cannula. 3 way part of the extension is connected to a 1/4 with luer lock prior to the MUF pump which is connected to maxlife hemofilter and pressure was monitored prior to filter. The post filter 3/16 tubing was connected to 3/16 luer lock connector connected to 3 way which is again connected to the 3 way port of 100 cm extension connected directly to the aortic cannula through 1/4 * 1/4 connector with luer lock. This modification was to facilitate the delivery of cardiolpegia directly though aortic cannula.



The perfusion circuit was primed and de-bubbled with sterofundin; 200 ml blood was added along with 45 ml of 20% albumin, 10 ml sodium bicarbonate, and 5 ml of mannitol. The crystalloid volume was chased to maximum extent possible. Total priming volume was 325 ml and it was aimed for maintaining 30% hematocrit on CPB.



CANNULATION

The aortic cannulation was done with 8 Fr Biomedicus cannula in innominate artery through 3mm gortex graft for the convenience of repairing the aortic arch and delivering antegrade cerebral perfusion. Cardioplegia delivery was planned through the aortic cannula. For that a 1/4*1/4 connector with leurlock was attached to the arterial line just prior to the cannula.

Venous cannulation done in right atrial appendage with a single stage medtronic dlp light house tip cannula.

On Cardio-pulmonary Bypass

Initiated bypass with 2.8 lit/min/sq m index flows and started cooling after dividing the Patent Ductus Arteriosis. The aortic line pressure was below 140 mmHg with mean right radial pressure of 45mmHg and femoral pressure of 30 mmHg. The cooling gradient between patient and hemotherm kept between 6 to 8 degree and the gradient between patient' nasopharyngeal and temperature was 5 degrees because of coartation of aorta. The targeted temperature of 20 degree nasopharyngeal temperature and rectal temperature of 25 degree was achieved in 20 minutes. Sodiun Nitro Prusside infusion was on to maintain the pressures. The first hematocrit on CPB was 32% and gradually hemodiluted accordingly to keep 24% hematocrit in deep hypothermia. Alpha stat blood gas managment was employed throughout the procedure.

Upon reaching the nasal temperature of 20 degree and rectal temperature of 25 degree, aorta was clamped distal to the innominate artery and descending aorta to perform the distal aortic arch. Left common carotid and subclavian artery clipped using anuerysm clips. At this time pump flow adjusted to 50 ml/kg to perfuse innominate artery and coronaries. Once the distal arch repair was completed, total circulatory arrest was employed for a minute and arterial line clamped to deliver cardioplegia, a clamp was placed in the innominate artery above the level of cannula position. Cardioplegia was delivered through the 100 cm extension with 3 way attached to the aortic cannula. Extra volume of 15 ml cardioplegia was administered in consideration of circuit priming volume. Once the delivery of cardioplegia was complete the clamp in the innominate artery was replaced down to the cannula to start antegrade cerebral perfusion through the isolated innominate artery, the pump flow was adjusted to 30 ml/kg at this point of time. After completing the arch repair the descending aortic clamp was taken off and de-airing performed in a retrograde manner. Aortic cross clamp was placed normally, the clips in the arch vessels removed and the systemic perfusion resumed. To inspect the deviated conal septum and ventricular septal defect a short TCA of 5 minutes was employed after 6 minutes of systemic perfusion. Ventricular septal defect was closed through pulmonary artery while slowly rewarming to 24 degree. Cross clamp released after VSD closure, Pulmonary artery incision sutured while slow rewarming to 35.8 degree nasopharygeal and 35.5 rectal temperature, CUF performed during this time. Patient was weaned off from CPB with stable hemodynamics.

A clinical overview at the time of weaning off CPB

Heart rate	140 bpm
Arterial pressure	55/30 mmHg
PA pressure	30/17 mmHg
CVP	8 mmHg
Saturation	99%
Hematocrit	27%



Ionotrope supports

Adrenaline	0.05 mics/kg/min.		
Milrinone	0.3 mics/kg/min.		
Calcium	100 mg/hour.		
CPB DETAILS			
CPB time	176 min.		
Cross clamp time	70 min.		
TCAtime	CA time 1+4+5 min.		
Coronary+innominate perfusion time		48 min.	
Selective innominate p	21 min.		
Conventional ultrafiltr	100 ml.		

Veno-arterial MUF was initiated after making sure that the circuit is free of air.

MUF performed for 15 minutes, during this time MUF pump kept 30 ml/min and arterial pump was kept at 10ml/min. There was no hemodynamic disturbances during MUF.

After MUF

Heart rate	140 bpm	
Arterial pressure	62/37 mmHg	
PA pressure	21/11mmHg	
CVP	5 mmHg	
Hematocrit	42%	

On MUF 170 ml volume was administered and a total volume of 255 ml was taken out. Transmembrane pressure was kept between 150mmHg to 230 mmHg.

Post operative performance

Patient was extubated after 73 hous of ventilation without any events.

Total transfusion recieved by the patient

PRBCs	280 ml.
Platelets	50 ml.
Cryoprecipitate	25 ml.



DISCUSSION

Innominate graft cannulation in aortic arch repair increases the convenience of both surgeon and the perfusionist. It avoids long TCA time during arch surgery and avoids the complications of pushing the cannula into innominate artery. We experienced less resistance in aortic cannula in this technique. Administering cardiolplegia through the aortic cannula will avoid another incision in the aorta and at the same time MUF circuit can be used for cardioplegia delivery. The use of 100 and 150 cm extensions for MUF reduces the priming volume of the circuit and improve the hemoconcentration rate, it also cause less temperature drift during MUF.

Doing arterio-venous in innominate cannulation increases the risk of cerebral stealing and it has got less risk of having cavitation, so veno arterial MUF is supposed to be ideal in patients where we opt for innominate cannulation. Hemodynamic stability is much better during veno arterial MUF compared to any other variations of MUF.

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