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Research Article

INCIDENCE AND DISTRIBUTION OF VARIOUS ARTERIAL TERRITORIES INVOLVED IN POSTOPERATIVE NEUROLOGICAL COMPLICATIONS IN PATIENTS UNDERGOING CARDIOVASCULAR SURGERY: A SINGLE CENTRE RETROSPECTIVE ANALYSIS

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ABSTRACT

INTRODUCTION: Neurological complications (stroke) remain a devastating complication after cardiovascular surgical procedures despite advances in perioperative monitoring and management. The incidence of neurological complications related to cardiovascular surgeries is comparatively very high and associated with high morbidity and mortality. The aim of this study is to evaluate the overall incidence of neurological complication in adult as well as pediatric patients and various pattern of neurological injury on non-contrast computed tomography head (NCCT) associated with various types of cardiovascular surgeries. **MATERIAL AND METHOD:** We retrospectively analyzed all the NCCT heads of the postoperative cardiovascular surgery patients done in immediate and early post-operative period (<7days) who developed postoperative neurological deficitbetween April 2016 to February 2020. The medical records of all these cardiac surgery patients were analyzed for various variants like total number of patients who underwent cardiovascular surgeries, various types of cardiac surgery done during the study period, demographic information, associated co-morbidities, various types of neurological complications, post-operative data and various spectrum of CT findings in the brain. **RESULT:** Total 12896 adult and pediatric cardiac surgeries were performed at our institute. Out of these, 1115 patients (8.6%) underwent CT brain for suspected neurological injury. Total215 patients (1.6%) had positive finding on their NCCT head. Out of 215 patients, 148 (68.9%) were adult patients while 67 (31.1%) were pediatric patients. Total 156 (72.5%) patients had ischemic infract (stroke) while hemorrhagic lesion present in 59 patients (27.4%). The various types of positive CT scan findings were- 156 ischemic infarct (72.5%), 20 intra-parenchymal haemorrhages (9.3%), 16 subdural haemorrhage (7.4%), 15 sub-arachnoid haemorrhage (6.9%), 01 cerebro-vascular thrombosis (0.4%) and 07 intra ventricular haemorrhage (3.2%). In adult patient pattern of ischemic infarct comprised middle cerebral artery territory in 42 patients (41.5%), posterior territory in 34 patients (33.6%), anterior cerebral territory in 7 patients (7.0%), multi-territory infracts in 11 patients (11.0%) and global ischemia in 6 patients (6.0%). Intra parenchymal hemorrhage was present in 17 patients (11.4%). In pediatric patient pattern of ischemic infarct included global hypoxic injury in 30 patients (54.5%), posterior cerebral artery territory in 9 patients (16.3%), middle cerebral artery territory in 8 patients (14.5%), multi-territory involvement in 5 patients (9.0%) and anterior cerebral artery territory in 3 patients (5.4%). In hemorrhage group 5 patients (7.4%) developed subarachnoid hemorrhage. **CONCLUSION:** In adult patients middle cerebral artery (MCA) territory infracts was common in infract group while Intra parenchymal hemorrhage (IPH) in hemorrhage group. In pediatric patient Global hypoxic injury (GHI) was common in infract group and Sub arachnoid hemorrhage (SAH) in hemorrhage group. Moreover, Non-contrast computed tomography (NCCT) of head is very useful in diagnosing early postoperative neurological complication in cardio-vascular surgeries and managing the complications accordingly.

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INTRODUCTION

Neurological complications (NC) aremajor cause of morbidity and mortality during the immediate and early postoperative period following cardiovascular surgeries (CS), with an incidence that varies widely from 25–79% [1-5,7,8,9]. A number of studies have demonstrated an incidence of ischemic stroke with motor deficit ranging between 2% and 6% among patients who have undergone myocardial revascularization, with even higher rates following valve replacement [1,2,3,6,7].They add to the consumption of health care resources and leads to functional limitations in surviving patients, so understanding of their etiology, pathogenesis, prevention, and management is utmost importantin management of these patients [3,6,8]. Risk factors for postoperative neurological complications include age, history of cerebrovascular disease, atherosclerosis, diabetes, recent myocardial infarction and carotid disease [1, 5, 7, 8, 12]. In addition to patientrisk factors, intraoperative events involving microemboli from the bypass circuit, air, intracardiac thrombi, aortic atheroma released during cross-clamping, as well as global hypo-perfusion have all been implicated as etiologies of postoperative neurovascular complications [7,8,11-15].

Various other mechanisms anticipated to elucidate the cerebral dysfunction consist of development of post operative cerebral edema, inflammatory cascade activation and gaseous or lipid particles micro-emboli [16]. Moody et al. proposed that following bypass surgery, the cerebral arterioles and capillaries dilate due to microemboli [17]. The development of post operative encephalopathy and delirium is usually due to adverse effects of anesthetic drugs, metabolic changes, ischemic lesions, hypotension, etc.Previous studies have examined the etiologyand predictors associated with neurological complications after cardiovascular surgery, few studies have evaluated the incidence and pattern of neurological injury in non-contrast computed tomography(CT) scans of the head, in the early postoperative period (<7 days postoperative). The aim of this study is to evaluate the overall incidence of neurological complication in adult as well as pediatric patients and various pattern of neurological injury on non-contrast head CT scans associated with various types of cardiovascular surgeries.

MATERIAL AND METHODS

Patient Data

We retrospectively analyzed all the NCCT heads of the postoperative cardiovascular surgery patients done in immediate and early post-operative period (<7days) who developed postoperative neurological deficitbetween April 2016 to February 2020. The study was approved by university ethics committee.The medical records of all these cardiac surgery patients were analyzed for various variants like total number of patients who underwent cardiovascular surgeries, various types of cardiac surgery done during the study period, demographic information, associated co-morbidities, various types of neurological complications, post-operative data and various spectrum of CT findings in the brain.

Inclusion criteria

Patients of all age group in which NCCT head was done for evaluation of neurological deficit in early post operative period after cardiac surgery from April 2016 to June 2022.

Exclusion criteria

1. All the post operative cardiac surgery patients in whom NCCT head was done after 7days.
2. Post operative cardiac surgery patients in which repeat NCCT head was done.

Stratification

The outcome data were then analyzed along with the findings on NCCT head. The outcome of these patients was broadly classified as: a) Type of neurological deficit, b) type of radiographic findings associated with the type of neurological injury and c) various spectrum of CT findings.

RESULTS

The total number of cardiovascular surgeries done at our hospital during the study period from April 2016 to February 2020 was 12896, the distribution of which is given in Table 1.

Table 1 Various types of cardiac surgeries done during the study period

S.No	Type of cardiovascular surgery	Total Number (n=12896)	Percentage (%)
1	Coronary artery bypass graft (CABG)	5385	42
2	CABG + Valve replacement surgeries (VRS)	509	4
3	Valve replacement surgeries	3001	23
4	Congenital cardiac disorders (CCCD)	2971	23
5	Peripheral vascular disease	676	5
6	Aortic surgery	354	3
	Total	12896	

Out of 12896 cardiovascular surgeries, 215 (1.6%) patients developed neurological complications in the early post operative period which constituted our study group. These patients were then further evaluated by non-contrast computed tomography head (NCCT) to know the various pattern and spectrum of lesion and various arterial territory involved. Out of 215 patients who developed neurological complications, 67 (31%) patients were of pediatric age group ranging from 2 months to 14 yrs who underwent surgeries for complex congenital cardiac disorders. Pediatric patients were mostly male and were not associated with any co-morbidities.

Table 2 Number of patients with neurological complications in various types `of cardiovascular surgery (CS)

S.No	Type of cardiac surgery	Number of patients,n=215	Percentage(%)
1.	CABG	39	18.1
2.	Valve replacement surgeries (VRS)	73	33.9
3.	Aortic surgery	22	10.2
4.	Congenital cardiac surgeries	67	31.1
5.	Peripheral vascular disease	14	6.5

Remaining 148 patients (69%) were adults ranging from 16 to 70 year. In the adult patient various co-morbid conditions include hypertension, ischemic heart disease, chronic kidney disease, diabetes mellitus and peripheral vascular disease. Out of 215 patients who developed neurological complications following cardiovascular surgeries, the type and total number of underlying cardiovascular surgical procedures are given in Table 2. The most common surgery performed was CABG followed closely with valve replacement surgeries, accounting

for 39 (18.2%) and 73 (33.9%) cases respectively. Out of the 12896 patients undergoing various forms of cardiovascular surgeries, the incidence of patients developing neurological complication in various categories of surgeries is shown in Table 3. Aortic surgeries (6.2%) and valve replacement subset of patients (2.4%) formed the highest group followed by congenital cardiac disorders (2.2%) to develop immediate/early post operative neurological complications.

Table 3 Incidence of neurological complications in various types of cardiovascular surgeries.

S.No	Type of cardiovascular surgery	Number of patients developed neurological complications/ total number of types of cardiovascular surgeriesperformed (n)	Percentage (%)
1	Coronary artery bypass graft (CABG)	39/5385	0.7
2	CABG + Valve replacement surgeries (VRS)	10/509	2.0
3	Valve replacement surgeries	73/3001	2.4
4	Congenital cardiac disorders (CCCD)	67/2971	2.2
5	Peripheral vascular disease (PVD)	14/ 676	2.0
6	Aortic surgery	22/354	6.2

Out of total patients who developed neurological complications, a total number of 215 positive CT scan findings were noted, 67 in pediatric age group and 148 in adult age group as given in Table 4,5 and 6.

Table 4 Types of Positive CT scan findings in Adult and Pediatric patients

S.No	Type of positive CT scan findings	Frequency of positive CT scan,n=215	Percentage (%)
1	Ischemic infarct	156	72.5
2	Intra-parenchymal hemorrhage (IPH)	20	9.3
3	SDH	16	7.4
4	SAH	15	6.9
5	CVT	1	0.4
6	IVH	7	3.2

IPH- Intra-parenchymal hemorrhage; SDH- Sub Dural hemorrhage; SAH- Sub arachnoid hemorrhage; CVT- Cerebral venous thrombosis; IVH- Intra ventricular hemorrhage

Taken together, ischemic infarct was the frequent CT finding as seen in 72.5% cases followed by IPH (9.3%). In adult subset, total 9925 patients underwent cardiac surgery, in which 148 patients developed neurological injury. In adult patients, ischemic infracts comprised of 68.2% and various arterial distribution comprised middle cerebral artery territory in 42 patients (41.5%), posterior territory in 34 patients (33.6%), anterior cerebral territory in 7 patients (7.0%), multi-territory infracts in 11 patients (11.0%) and global ischemia in 6 patients (6.0%). Intra parenchymal hemorrhage was present in 17 patients (11.4%) followed by SDH in 12 patients (8.1%), SAH in 10 patients (6.7%), IVH in 7 patients (4.7%) cerebral venous thrombosis (CVT) was evident in one patient. The positive NCCT findings in adult patients are given in Table 6. Location, arterial territory and total number of territories involved in adult patients mentioned in Table 9. In pediatric subset, 2971 pediatric cardiac surgeries were performed at our institute. 67 patients (2.25%) developed neurological complications. Fifty-five patients (82%) developed ischemic infract while 12 patients (18%) had intracranial hemorrhagic as mentioned in Table 5. Pattern of ischemic infarct in pediatric subset included global hypoxic injury in 30 patients (54.5%), posterior cerebral artery territory in 9 patients (16.3%), middle cerebral artery territory in 8 patients (14.5%), multi-territory involvement in 5 patients (9.0%) and anterior cerebral artery territory in 3 patients (5.4%) as given in Table 8. In patients with intracranial hemorrhage, 5 patients (7.4%) developed subarachnoid hemorrhage, 4 patients (5.9%) developed subdural hemorrhage and 3 patients (4.4%) developed intra-parenchymal hemorrhage as mentioned in Table.5.

Table 5 Positive CT scan findings in Pediatric patients.

S.No	Type of positive CT scan findings	Frequency of positive CT scan,n=67	Percentage (%)
1	Ischemic infarct	55	82.0
2	Intra-Parenchymal Hemorrhage (IPH)	3	4.4
3	SDH	4	5.9
4	SAH	5	7.4

IPH- Intra-parenchymal hemorrhage; SDH- Sub Dural hemorrhage; SAH- Sub arachnoid hemorrhage

Table 6 Positive CT scan findings in adult patients.

S.No	Type of positive CT scan findings	Frequency of positive CT scan n=148	Percentage (%)
1.	Ischemic infarct	101	68.2
2.	IPH	17	11.4
3.	SDH	12	8.1
4.	SAH	10	6.7
5.	IVH	7	4.7
6.	CVT	1	0.6

IPH- Intra-parenchymal hemorrhage; SDH- Sub Dural hemorrhage; SAH- Sub arachnoid hemorrhage; CVT- Cerebral venous thrombosis; IVH- Intra ventricular hemorrhage

Table 7 Various arterial territories involved by the Infarcts in different patients.

S. No	Arterial territory of Infarct	Total no of arterial territories involved, n=156	Bilateral	Unilateral	Percentage (%)
1.	MCA	52	25	27	33
2.	ACA	15	3	12	9.6
3.	Posterior Circulation	22	17	5	14
4.	Multi territory	19	-	-	12
5.	Global hypoxic injury	42	-	-	27
6.	Watershed Area	6	-	-	4

ACA - Anterior cerebral artery; MCA - Middle cerebral artery; PCA - Posterior cerebral artery; GHI – Global hypoxic injury

In ischemic infarcts the various arterial territories involved in both adult and pediatric patients has been given in Table 7. 52 patients (33%) had MCA territory infarct, with 27 unilateral and 25 bilateral arterial territory involved. 22 patients (14%) had posterior circulation infarct. 19 patients (12%) had multi-territory. 15 patients (9.6%) had ACA territory infarct, 12 patients had unilateral ACA territory infarct, 3 had bilateral

territory infract. Watershed infarcts were seen in 6 (4%) patients.

Table 8 Location, arterial territory and total number of territories involved in Pediatric patients.

S. No	Location of infract	Arterial territory involved	Pattern	Total no. of territory involved (n)
1.	Frontal- Parietal-Occipital lobe(cerebrum) with basal ganglia and thalamus	ACA-MCA-PCA-thalamic branch	GHI (CT scan suggestive)	30
2.	Occipital Lobe (maximum)	PCA (maximum)	Posterior circulation	9
3.	Frontal- Parietal Lobe (maximum)	ACA-B/L MCA (maximum)	MCA territory circulation	8
4.	Frontal lobe - Temporal lobe-Parietal lobe	U/L ACA-MCA-PCA	Multiple territory involvement	5
5.	Frontal lobe	B/L ACA	Anterior circulation	3

ACA - Anterior cerebral artery; MCA -Middle cerebral artery; PCA- Posterior cerebral artery; GHI – Global hypoxic injury; U/L- Unilateral; B/L- Bilateral

Table 9 Location, arterial territory and total number of territories involved in adult patients.

S. No	Location of infract	Arterial territory involved	Pattern	Total number of territories involved (n)
1.	Parietal lobe-Temporal lobe-Basal ganglia	U/L and B/L MCA	MCA territory	42
2.	Occipital lobe - Thalamus	PCA (maximum B/L) and Thalamic branch of PCA	osterior circulation	34
3.	Frontal lobe	ACA	Anterior circulation	7
4.	Frontal lobe - Temporal lobe-Parietal lobe	ACA-MCA-PCA	Multiple territory involvement	11
5.	Frontal- Parietal-Occipital lobe with basal ganglia and thalamus (mostly B/L lesion)	ACA-MCA-PCA-thalamic branch	GHI (CT scan suggestive)	6

ACA - Anterior cerebral artery; MCA - Middle cerebral artery; PCA - Posterior cerebral artery; GHI – Global hypoxic injury; U/L- Unilateral; B/L- Bilateral

DISCUSSION

We carried out retrospective study of all the NCCT heads done in our department from April 2016 to June 2020 on the post cardiac surgery patients who developed various neurological complications (NC) in the immediate post operative period. The total number of CS done in our hospital during the study period was 12896. The most common surgery performed was that for Coronary artery bypass graft (CABG), which was performed in 42% patients followed closely by Valve replacement surgeries which was performed in 23% cases and Congenital cardiac disorders (CCCD) constituting 23%.

The most important cause of morbidity and mortality in the immediate post operative period following cardiac surgeries are neurological complications like ischemic infract and hemorrhagic stroke. The incidence of neurological deficits following cardiovascular surgery varies from 25% to 79% while 6% comprises of focal deficit [1-10]. In the study by Beaty et al. the incidence of neurological complications in early post operative period of cardiovascular surgery patient was 6.1% [18]. In a study by Bucerius et al. the author's prospective data on 16,184 consecutive patients undergoing cardiac surgery reported an overall incidence of 4.6%. [6]. Several previous studies have demonstrated that permanent neurologic deficits occur in as many as 6% of patients [10,11,13,14]. In our current retrospective large series study the incidence of stroke was 1.6% depicting an overall improvement in the incidence of neurological complications following cardiovascular surgery owing to improvement in perioperative management and surgical technique. Further, our study population had younger patients and lesser associated co-morbidities undergoing coronary artery bypass procedures and valve replacement surgeries.

In our study, amongst the patients developing complications following cardiac surgeries, the most common surgery involved was coronary artery bypass grafting (CABG) followed by valve replacement surgeries (VRS). According to the Kuroda et al. the incidence of neurological complication in CABG (11%) was higher as compared to valve surgeries (7%) due to the coexisting cerebro-vascular disease and prolonged cardio-pulmonary bypass time which in turn leads to cerebral embolism and cerebral hypo-perfusion. The other risk factors they attributed for higher incidence are older age, diabetes mellitus, hypertension, cerebrovascular disease, and increased cardiopulmonary bypass time [19]. In our study, the incidence of neurological complication was higher in valve replacement patients (2.4%) as compared to patients undergoing CABG (0.7%). Multivariate analysis revealed age, previous CVA, and chronic renal impairment as predictors of stroke in their study. It has been established by several studies that the incidence of ischemic stroke and motor deficit ranging from 2 to 6% in cases of myocardial revascularization is more than with valve replacement surgeries [2-5]. These are primarily related to systemic hypoperfusion or peri-operative embolism dislodging from the cardiac chambers and aorta or combination of these two processes. However, in our study when the incidence of neurological complications in various subsets of surgeries was considered, it was observed that aortic surgeries (6.2%) and valve replacement surgery (2.4%) patients formed the highest group followed by congenital cardiac disorders (2.2%) and CABG + Valve replacement surgeries (2.0%) to develop post operative neurological complications. These surgeries were usually associated with dislodgment of the emboli in the cerebral circulation. In our study, the incidence of neurological complications in valve replacement surgery (2.4%) were more as compared to the CABG (0.7%) as the chances of emboli formation were more with valve surgeries than with CABG. Furthermore, the lower incidence of neurological complications in CABG patients are attributed to younger age, off pump CABG and lesser associated co-morbidities, however this needs further evaluation and predictors of lower incidence of neurological complications in CABG patients are under investigation at our institute. Bucerius et al. in their analysis revealed that advanced age is not a cause of stroke per se but rather a marker of increased atherosclerotic burden [6]. This finding is consistent with the findings of our study as advanced age has not been found to be the cause of neurological complications in patients undergoing CABG. The incidence of stroke following peripheral vascular disease was 2.0% which could be attributed to increased risk of atherosclerotic

embolization as well as impaired autoregulation of cerebral blood flow [8,20].

Salazar et al. in their study revealed an incidence of ischemic infract to be 72% of the total positive brain imaging studies and an overall incidence of 2.5% (151 of 5,971). In our study, out of 215 patients with neurological complications evaluated, evidence of ischemic stroke was present in 156 patients (72.6%). The overall incidence of ischemic stroke confirmed by brain imaging studies was, therefore, 1.2% (156 of 12896). Thus, our study revealed overall lower incidence of ischemic stroke [21]. CT scan is the most widely and easily available neuro-imaging modality used for diagnosis and evaluation neurological complications. NCCT is the most common modality to find out the cause of immediate and early post-operative period neurological complications occurring in the patients undergoing cardiovascular surgeries [1,2,8]. It is used to evaluate the size, location and distribution of the infarct/hemorrhage. As compared to magnetic resonance imaging (MRI), non-contrast computed tomography head (NCCT) is rapid, cheap and most widely used modality. Non-contrast computed tomography head (NCCT) is primarily used to differentiate hemorrhage from non-hemorrhagic stroke.

In adult patient subset pattern of ischemic infarct comprised middle cerebral artery territory in 42 patients (41.5%), posterior territory in 34 patients (33.6%), anterior cerebral territory in 7 patients (7.0%), multi-territory infracts in 11 patients (11.0%) and global ischemia in 6 patients (6.0%). Salazar et al. showed similar pattern of cerebral arterial territory involvement where infarctions occurred in the territory of the middle cerebral artery in 78% of patients, the posterior cerebral artery in 28%, the anterior cerebral artery in 7% and multiple vascular territories in 36% of patients. Our study is in accordance with the findings of Salazar et al. wherein MCA territory infracts were common. Girdauskas et al. in their study demonstrated the higher incidence of posterior territory infract (75%) followed by middle cerebral territory infract (40%), in their study they postulated thatend hole aortic cannulas direct a high-velocity jet at the left carotid orifice and may be responsible for a large proportion of perioperative strokes. The jet is directed at both the left carotid and left subclavian arteries explains the posterior distribution of strokes, emboli in the proximal left subclavian artery may travel up the left vertebral artery and enter the posterior circulation. In most of our patients with MCA infract there was unilateral predisposition which is in accordance with the study of Girdauskas et al. where in one third of their patients, had unilateral distribution of MCA infarct [22]. Barbut and colleagues have demonstrated the higher preponderance of involvement of PCA and MCA territory in their study and have attributed atheromatous embolization as a possible cause of perioperative stroke [23]. The commonest finding on NCCT head was ischemic infarct and second common was intra parenchymal bleed (IPH). Intra cranial hemorrhage overall accounted for 0.45% of the positive CT scan with neurological complication, while in adult patients it accounted for 31.7% in which intra parenchymal hemorrhage (IPH) accounted for 11.4% followed by SDH accounting for 8.1%. The least incidence of intracranial hemorrhage was IVH accounting for 4.7%. Our findings of intracranial hemorrhage are in accordance with the findings of Hogue et al. in terms of distribution of hemorrhagic lesions. In their study, intraparenchymal hemorrhage (IPH) was the most frequent 41.21% followed by subdural hematoma (SDH) 22.53% and subarachnoid hemorrhage (SAH) accounted for 3.85%. They attributed any factors leading to cerebrovascular injury or fluid shifts with fluctuations in cerebral volume during pre, intra and post operation of cardiac surgery leads to tearing of the bridging dural veins that might cause intracranial hemorrhage [24].

In pediatric subset, the overall incidence of neurological injury was 2.25% in which incidence of ischemic stroke is 1.8%. Global hypoxic injury accounts for 82% of cases in ischemic infract subset. Chen et al. in their study demonstrated an incidence of ischemic stroke to be 10% and attributed thromboembolism and hypoperfusion for stroke. Lower birth weight, preoperative mechanical ventilation, and lower hematocrit during CPB were identified as risk factor for stroke [25]. Importantly, other variables such as duration of CPB and the use of DHCA, were not significantly associated with an increased risk of stroke. Domi and colleagues demonstrated the frequency of stroke in children with congenital heart disease undergoing cardiac surgery to be 5.4 cases per 1000 children. However, they revealed longer duration of cardiopulmonary bypass and reoperation as a risk factor for stroke. Alvarez et al. reported an incidence of stroke in pediatric patients as 4.2%. They showed that patients with neurological complications had a longer bypass time, longer aortic cross time, longer hospitalization in intensive care, longer duration of mechanical ventilation and an increased inotropic support. However, the incidence of ischemic stroke in pediatric population in our study is less as compared to the incidence quoted in literature [26].

Several limitations of this study can be identified. First, this is a retrospective study and is therefore, subject to limitations in data recording which may introduce bias. Second, this study evaluates CT scan data for the first 7 post operative days with no long term follow up. Therefore, it is unable to address issues of lesion progression on consecutive CT scans, neurologic recovery or chronic disability beyond final disposition. Third, the contribution of postoperative atrial fibrillation to neurological complication was not studied, due to the small number of patients with atrial fibrillation, however, none of them developed CVA and so, it cannot be a predictor of this event.

CONCLUSION

In summary stroke is a devastating complication of cardiac surgery and continues to affect approximately 5% of patients. The incidence of stroke varies with different surgical procedures with the lowest risk observed for patient undergoing beating heart CABG. In our retrospective study of the NCCT scan of the head in the immediate and early post-op period, it was found that the CT scan was a very useful imaging tool in timely diagnosing neurological complications in patients recently undergone cardiac surgeries, thereby facilitating decision-making and clinical management as indicated. The commonest CT scan finding was ischemic infarct and second most common was intra parenchymal bleed. the incidence of neurological complication following cardiac surgery is lower in the current era than reported in the past at our institute. Furthermore, decrease in the incidence of neurological complication over time highlights the importance of identifying modifiable underlying causes of intra operative and

postoperative neurologic complications. Future observations will demonstrate whether this low incidence of postoperative neurologic complications can be sustained or even further reduced.

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Conflicts of interest/Competing interests

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