Malignant middle cerebral artery infarct: A clinical case report

Leung, Kwan Yee (Queenie)[1,2], Jala, Sheila[2], Elliott, Rosalind[2].*

[1]Manly Hospital, Northern Sydney Local Health District, 150 Darley Road, Manly NSW 2095, Australia

[2]Royal North Shore Hospital, Northern Sydney Local Health District, Reserve Road, St Leonards NSW 2065, Australia

Abstract

Background:
Ischaemic stroke accounts for 87% of strokes and occurs when a clot or a thrombus blocks a blood vessel, cutting off blood flow to a part of the brain. If large areas of brain are affected, space-occupying oedema may result, leading to rapid neurological deterioration, coma and death. Malignant middle cerebral artery infarction (MMCAI) is a life-threating ischaemic stroke involving the whole middle cerebral artery (MCA) territory and comprises up to 10% of MCA infarctions.

Methods:
We report the case of a 62 year old female 'Mary' who presented with a MMCAI together with a summary of the most recent and relevant evidence for treatment options in terms of survival and quality of life for her. We also focus on the vital role of the nurse in Mary's care and treatment.

Results:
Intravenous thrombolysis and endovascular clot retrieval (ECR) during the hyperacute phase have been shown to improve outcomes but Mary did not meet the criteria for thrombolysis and received unsuccessful ECR. Her neurological condition deteriorated so she underwent surgical decompression, which is one of the major advances for MMCAI treatment together with expert neuro critical care nursing. Mary made a good functional recovery, returning home to live independently.

Conclusion:
This case highlights the need to consider all contextual and patient preferences in relation to treatment options. In addition the case emphases the vital role the neuro critical care nurse specialist plays in the complex assessment and treatment of this patient who experienced a MMCAI and underwent complex interventions.

Keywords: stroke, middle cerebral artery infarction, case study, critical care, critical illness

Introduction:

Malignant middle cerebral artery infarction (MMCAI) is the worst form of ischaemic stroke as it involves an infarction of nearly the whole middle cerebral artery (MCA) territory (>50% of the MCA territory on Computed Tomography [CT]). MMCAI is also characterised by a reduction in blood supply of >66% together with a large area of dead tissue on CT (infarct volume of >82 mL within 6 hours of onset on MRI and infarct volume of >145mL within 14 hours of onset on MRI) (Huttner & Schwab, 2009; Oppenheim et al., 2000; Thomalla et al., 2003; Vahedi, Vicaut, et al., 2007) which is usually reflected in significant motor deficits resulting in an inability to move independently. MMCAI is the most severe form of stroke and comprises up to 10% of all MCA territory infractions (Hacke et al., 1996); the annual incidence is 10-20 per 100,000 people (Treadwell & Thanvi, 2010). Unwanted sequela is space-occupying oedema leading to rapid neurological deterioration, irreversible coma and death. The prognosis is generally poor, and death occurs in approximately 80% of cases as a result of transtentorial herniation and brainstem compression (Back, Nagaraja, Kapur, & Eslick, 2015).

Treatment options include intravenous (IV) thrombolysis within 4.5 hours of stroke onset, endovascular clot retrieval (ECR) within 24 hours of stroke onset and surgical decompressive surgery.

Questions or comments about this article should be directed to Leung, Kwan Yee (Queenie)
Email address: kwanyee.leung@health.nsw.gov.au

DOI: 10.21307/ajon-2017-008

Significant studies have shown that early decompressive craniectomy (DC) in patients aged <60 years within 48 hours of onset of malignant stroke have significantly reduced mortality (22% versus 71% – pooled analysis; numbers needed to treat =2) (Vahedi, Hofmeijer, et al., 2007); however, the efficacy of this treatment on functional outcome is inconclusive.

This paper provides a summary of selected published studies of relevant current treatment options for a patient who presented with malignant MCA infarct. Using the case study as an example, current treatment options including thrombolysis, ECR and DC are examined together with the research evidence for these treatments. In addition the vital role of the neuro critical care nurse specialist is highlighted.

Case Study

This case study follows Mary's (a pseudonym) journey from the time when her daughter found her collapsed on the floor in her home to the day she was discharged from the hospital. For the purposes of this paper, the clinical guideline used at the metropolitan tertiary referral facility (location of a hyperacute stroke service) in which Mary was treated (in Australia) was used as a framework. Mary gave written consent for the publication of this paper.

Presentation and health history

Mary, a 62 year old female, was found by her daughter at 03:45 on the bathroom floor of her home. Her daughter stated that Mary was apparently well when she last saw her before bed time at approximately 22:00. An ambulance was called and on examination, Mary had a left sided facial droop, gaze palsy, left visual neglect, dense left hemiparesis and sensory neglect. She was immediately transported to the nearest hospital but later was transferred to the tertiary referral facility (a 20 -30 minute drive), a thrombolysis centre of the local health district for hyperacute stroke management. Ninety minutes after being found by her daughter Mary was screened for the use of thrombolysis. Mary presented to the tertiary referral facility outside of the thrombolysis treatment window (that is >4.5 hour after stroke onset). She had a history of atrial fibrillation and aortic and mitral metallic valve replacements on warfarin (anticoagulant); hypertension managed with olmesartan/hydrochlorothiazide (a combination of angiotensin II receptor blocker and diuretic); and dyslipidaemia treated with simvastatin (lipid lowering).

On arrival, Mary was haemodynamically stable despite the presence of atrial fibrillation. All standard investigations were carried out according to the clinical guideline for stroke management including rapid clinical assessment, recommended imaging: plain CT brain scan, CT angiogram and CT perfusion, and blood tests (Stroke Foundation, 2017). At this time Mary's clinical assessment revealed a National Institute of Health Stroke Scale (Brott et al., 1989) score of 19, which correlates with 'severe stroke'.

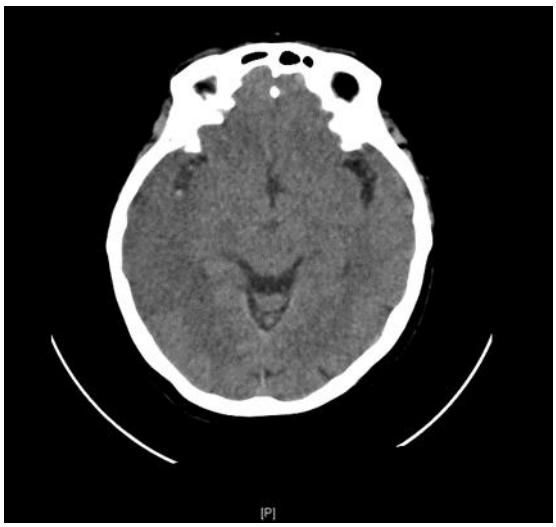

Figure 1. Computerised tomography scan

An urgent CT scan showed a loss of grey-white matter differentiation in the right insular cortex, the inferior aspect of the right frontal lobe, at the right temporal lobe and inferior aspect of the right parietal lobe (Figure 1); the CT angiogram revealed an occlusion of the right proximal M2 artery. In addition, CT perfusion findings consistent with an established infarct involving the right insula, inferior aspect of the right frontal lobe and anterior right temporal lobe were present. There appeared to be a moderate to large penumbra associated with the infarct (Figure 2). Her serum International Normalised Ratio (INR) was subtherapeutic (1.5); this indicated an inadequate anticoagulation to prevent complications related to her metallic valves and her serum creatinine level of 167umol/L revealed a degree of renal impairment.

Treatment during the hyperacute phase

Mary presented to the tertiary referral facility outside of the thrombolysis treatment window (that is >4.5 hour after stroke onset). Until recently, IV tissue plasminogen activator (tPA) was the only medical therapy approved

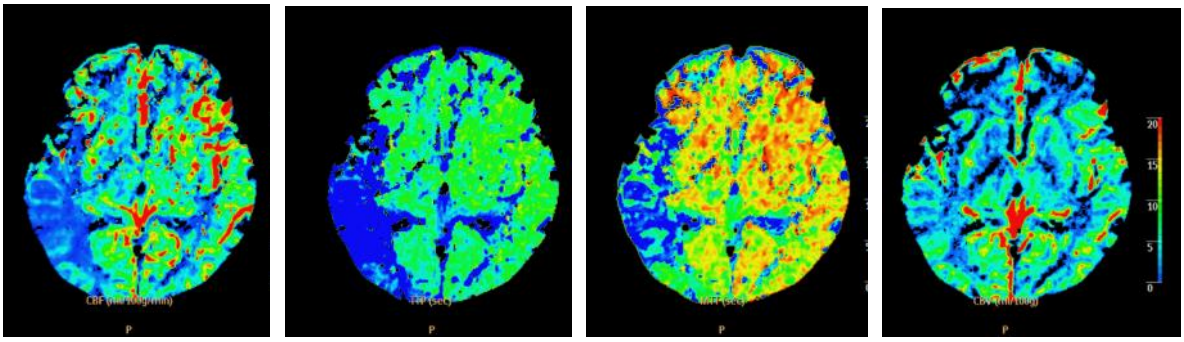

Figure 2. Computerised tomography perfusion scan

for the treatment of stroke during the hyperacute stage (<4.5 hours from onset of stroke symptoms). Approximately one third of the patients treated with IV tPA alone achieve full recovery (Hacke et al., 2008).

A meta-analysis from nine randomised controlled trials (RCTs) (n=6756) found that the earlier patients began thrombolysis with altepase, the better the outcome (Emberson et al., 2014). A good outcome is defined by a modified Rankin Score (mRS) (Rankin, 1957) of 0-1 (i.e. symptom free with no loss of function) at 3-6 months. Three different altepase treatment sub-categories based on time from symptom onset were altepase administered: within the first 3 hours of onset; between 3 hours to 4.5 hours of onset; and between 4.5 hours to 6 hours of onset. Within these three sub-categories: 1549 patients received altepase within the first 3 hours of onset had a good outcome 32.9% versus 23.1% (OR 1.75 95% CI 1.35-2.27); 2768 patients who received altepase after 3 hours of onset but within 4.5 hours had a good outcome 35.3% versus 30.1% (OR 1.26 95% CI 1.05-1.51); and 2394 patients found that patients who received alteplase more than 4.5 hours of onset but within 6 hours had a good outcome 32.6% versus 30.6% (OR 1.15, 95% CI 0.95-1.40) (Emberson et al., 2014). Results showed that 5024 patients 80 years or younger who had a good outcome was 39.4% versus 33.9% (OR 1.25 95% CI 1.10-1.42) who did not (Emberson et al., 2014). Of the 1729 patients older than 80 years, 17.6% had a good outcome and 13.2% did not (OR 1.56 95% CI 1.17-2.08) (Emberson et al., 2014). Therefore a widely accepted recommendation for the treatment of stroke is IV tPA (0.9mg/kg, maximum dose 90mg) to be administered within 3 hours of onset of ischemic stroke (Class I, Level of Evidence A)' (Powers et al., 2018).

Thrombolysis should commence as early as possible (within three hours) after stroke onset but may be used up to 4.5 hours after onset (Wardlaw, Murray, Berge, & del Zoppo, 2014). The complications of IV thrombolysis including intracranial haemorrhage and angioedema (Emberson et al., 2014; Powers et al., 2018) are significant and must be considered on an individual basis.

The time of her onset of stroke to the time she was assessed in the emergency room was seven and a half hours, which was still within the ECR treatment window (24 hours from stroke onset) (Nogueira et al., 2018). Current stroke guideline states that undergoing ECR is beneficial beyond six hours of stroke onset if a CT angiogram shows a large vessel occlusion (LVO) (Stroke Foundation, 2017). After Mary's son provided informed consent for the procedure, ECR for recanalization was performed. Recent trials have shown that ECR significantly improves functional independence in patients with a large vessel occlusion, a large CT perfusion mismatch and a good collateral circulation (Lambrinos et al., 2016).

A meta-analysis of five major trials revealed that ECR led to significantly reduced disability at 90 days compared with control (adjusted cOR 2.49, 95% CI 1.76–3.53; p<0.0001) (Goyal et al., 2016). The number needed to treat with ECR to reduce disability by at least one mRS level was 2.6 (Goyal et al., 2016). As a result of these impressive outcomes, the current American Heart Association/American Stroke Association recommends that patients should receive ECR if they meet the criteria (Class I, Level of Evidence A) (Powers et al., 2018) which includes stroke symptoms within 24 hours of onset or time last known well in wake-up stroke; a non-contrast CT without a large infarct (>1/3 MCA territory) or haemorrhage; and a CT angiogram (aortic arch to vertex of the brain) showing a large vessel occlusion of the internal carotid artery, M1 (first segment) or proximal M2 branches of the MCA or the basilar artery (Lambrinos et al., 2016; Powers et al., 2015). Mary's MMCAI was extensive

and she met many of these criteria i.e. a moderate to large penumbra associated to infarct and an occlusion of right M2 artery.

After the ECR, Mary was admitted to the neurosurgical Intensive care unit for more continuous monitoring of her condition. Neurologically she was alert. Her GCS after the ECR was 13/15 (Eye opening=3, Verbal response=4, Motor response=6) and her National Institute of Health Stroke Scale score was 15 (Answers both questions incorrectly =2, partial facial palsy=2, no movement on left arm=4, no effort against gravity on left left=3, partial sensory loss=1, severe aphasia=2, and partial neglect=1). Her respiratory function was good; she was maintaining her own airway and was breathing without difficulty. Haemodynamically she was stable; normotensive without support with vasoactive medication, despite atrial fibrillation (heart rate: 65-105bpm) and she was normothermic.

Day 1 after the stroke, a repeat CT scan revealed an acute cortical and intraparenchymal haemorrhage involving the right cerebral hemisphere with moderate marked mass effect. The infarction may increase in size during the acute phase causing clinical deterioration resulting from raised intracranial pressure (ICP) and tentorial herniation (Neugebauer et al., 2016). Conservative medical management, including hyperventilation, mannitol and sedation aiming to reduce oedema and mass effect in malignant MCA infarctions is considered minimally effective with associated high mortality (Powers et al., 2018) so this was not a treatment option. A DC procedure was therefore considered.

A family conference was led by the neurology medical team and facilitated by the neuro critical care nurse specialist. The neurology consultant explained to the family that Mary was likely to deteriorate as there was evidence of haemorrhagic transformation and swelling. In addition, the team explained the controversy and uncertainty regarding DC, especially in Mary's age group. They were careful to discuss the likelihood that the procedure would increase her chances of survival but would not necessarily reverse her current neurological deficits and that many patients in a similar condition are then dependent on others afterwards. The nurse encouraged the family to share information about Mary: her wishes, perspective on life and current quality of life. The family was informed that DC is a major operation requiring prolonged treatment in intensive care, including mechanical ventilation and its associated risks. In particular the need to reverse Mary's anticoagulation was a concern (risk of recurrent stroke was high as she had a metallic mitral valve and was in AF). A neurosurgical opinion to explore this treatment option was offered and the neurosurgical team was consulted. The family were of the opinion that Mary would have considered her functional deficit and dependence on others acceptable. The family provided informed consent for DC surgery if her neurological condition deteriorated.

Forty-two hours after the onset of stroke symptoms Mary's level of consciousness decreased (GCS 12 i.e. Eye opening=2, Verbal response=4, Motor response=6) and the neurosurgical team was immediately notified. Mary underwent a DC soon afterwards.

Three initial RCTs conducted in Europe revealed an excellent to favourable outcome for early DC for MCI for patients younger than 60 years (absolute risk reduction in mortality of 50% with 43% of survivors able to walk at six months) (Vahedi, Hofmeijer, et al., 2007). However, three recent RCTs in which patients >60 years were included reported worse outcomes for early DC for MCI. None of the older patients achieved an excellent functional outcome (mRS 0-2) and very few patients reached mRS 3 (Streib, Hartman, & Molyneaux, 2016). An Absolute Reduction Incidence (ARI) of 4% and numbers needed to treat 25 indicates favourable outcomes and for unfavourable outcomes, the ARI was 32.5% and numbers needed to treat was 3.1 (Streib et al., 2016). The decision to proceed with DC in Mary's case was based on the knowledge that it would likely improve her chances of survival but not necessarily her functional recovery together with information provided by the family.

The contemporary philosophy of nursing encompasses a holistic view of the person in order to deliver patient centred care (McCormack, 2003); nurses are required to know the patients' and their carers' perspectives on life. Quality of life (QoL) studies had been conducted and three major outcomes including functional status, depression and QoL have been explored after DC (Green, Demchuk, & Newcommon, 2015; McKenna, Wilson, Caldwell, & Curran, 2012; Middelaar, Nederkoorn, Worp, Stam, & Richard, 2015; Rahme, Zuccarello, Kleindorfer, Adeoye, & Ringer, 2012). Main assessment tools used to assess functional outcomes include the modified Rankin Scale (mRS) and Barthel Index (BI) (Green et al., 2015; Rahme et al., 2012) and the Zung Self-Rating Depression Scale and Hospital Anxiety and Depression scale (HADS) were used to assess depres-

sion outcome (McKenna et al., 2012; Rahme et al., 2012). Questionnaires or visual analog scale were used to assess QoL outcomes (Middelaar et al., 2015).

Of note in a study examining functional outcome between 3-114 months (mean: 19 months) after experiencing a stroke (n= 156, mean age: 50), moderate disability (mRS 4) was reported in 46%, severe disability was reported in 10% and a further 41% had some disability (mRS □ 3) (Rahme et al., 2012). In the same study depression was reported in 56%. and over 76% of patients were satisfied with life (Rahme et al., 2012) Many patients in these studies state that they would consent again for DC (Green et al., 2015; McKenna et al., 2012; Rahme et al., 2012).

Based on these results MMCAI patients after DC appear to experience moderate to severe disability and varying degrees of depression. One study showed some patients had a relatively good mood as they were able to maintain close relationships with families and friends, whereas others experienced depression (Green et al., 2015; Rahme et al., 2012) because of their inability to return to their pre-illness function and lifestyle. Other frequent findings include neuropsychological impairments (McKenna et al., 2012), alterations in personality and loss of independence (Green et al., 2015).

However, the findings for QoL and patient satisfaction showed that despite their physical disability, their QoL and satisfaction with life remained high. One study stated that patients reported only a small decrease in QoL long term (7-51 months) when compared to the general population (Middelaar et al., 2015). This finding contradicted the neurosurgeons or neurologists' perceptions that patients had a poorer QoL due to severe disability after DC. The review suggested that patients had better coping mechanisms than previously thought, despite their poor physical functioning and dependence on others for the activities of daily living (Middelaar et al., 2015). This may have been a result of response shift (a recalibration in the perception of QoL over time after experiencing a disability). Regardless, clinical guidelines for stroke management recommend that DC is offered to all MMCAI patients if extensive discussion about the risks and benefits is undertaken (Stroke Foundation, 2017).

Intra-operatively, there were signs of vasoparalysis in Mary's brain but later pulsation returned. Four burrholes and a large craniotomy were performed (and two parts of skull bone were inserted in a fat pouch in her abdominal cavity). In order to monitor ICP, an intraparenchymal catheter was inserted (Codman EXPRESS® Monitoring System). Mary experienced episodes of asystole and long cardiac sinus pauses but these resolved without the need for treatment.

Early recovery and rehabilitation after decompressive craniectomy:

Mary was admitted to neurosurgical intensive care unit after DC. Supportive care and treatment of acute complications were established. Her assessment findings indicated that she was breathing without difficulty or the assistance of an artificial airway or respiratory support other than 2L/min of oxygen via nasal cannula and was haemodynamically stable (systolic pressure: 100-140mmHg). Her neurological assessment revealed that her eyes opened to voice, she obeyed commands although she was confused (GCS 13/15: E=3, V=4, M=6). She had normal power in her right arm and leg but mild weakness in her left arm and leg. Her pupils were equal and reacting briskly to light. A repeat CT brain scan showed an increase in the acute haemorrhage. There was also some slight worsening of the mass effect and midline shift with a slight increase in uncal herniation (Figure 3).

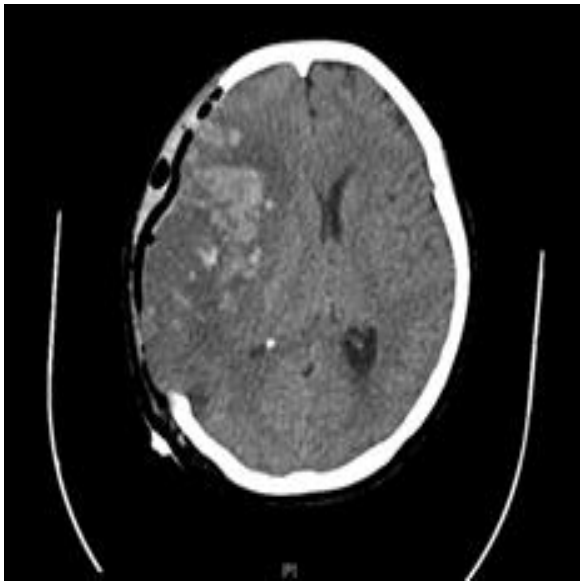

Figure 3. Repeat Computerised tomography scan after the decompressive craniectomy (DC)

She was enterally fed via a nasogastric tube (NGT). Mary developed deep vein thrombosis (DVT) and she was anaemic (haemoglobin (Hb): 79 g/L). She was treated with intravenous heparin and an iron infusion. Both the medical and nursing team regularly

provided updates of Mary's progress to her family.

The goal of post-operative care was to prevent or minimize complications related to anaesthesia and the surgical procedure. The focus was on smooth and timely emergence from anaesthesia while optimizing haemodynamic, respiratory and electrolyte conditions (Bose & Luoma, 2017; Liddle, 2013). This is vital to ensure adequate brain perfusion and healing because postoperatively the body undergoes significant physiological stress that may be manifested as fluctuations in homeostasis. This stress state is modulated by changes in sympathetic tone that controls body temperature and vascular tone (Tsaousi, Pourzitaki, & Bilotta, 2017).

Neurosurgical procedures have an overall complication rate of 14.3% (Badenes, Prisco, Maruenda, & Taccone, 2017). Moreover, patients have a high risk of experiencing neurological complications postoperatively and require advanced (ICP) neuromonitoring and frequent neurological assessment. deep vein thrombosis rates after craniectomy are as high as 34% (Nyquist et al., 2016). Current evidence supports combined mechanical and chemical thromboprophylaxis within 24 hours after surgery (Tsaousi et al., 2017). However, there is a higher risk of postoperative haemorrhage for patients who receive heparin (Wang et al., 2017). It is therefore important to monitor closely for signs of postoperative haemorrhage, particularly intracranial haemorrhage (ICH). Which can occur in 1-3% of cases with mortality rates as high as 30% (Siegemund & Steiner, 2015). Neuro critical care nurse specialists can positively affect the mortality rate by identifying signs of neurological deterioration early, alerting the neurosurgical team and preparing the patient for surgery. This is particularly important within the 24 hours after surgery when the risk of haemorrhage is greatest (Nittby, Maltese, & Ståhl, 2016).

Comprehensive and frequent neurological assessments and vital sign observations are the cornerstones of post-operative neurosurgical care in the unit in which Mary was treated (Northern Sydney Local Health District, 2009). In addition, Mary's post-operative care included: 1) positioning the head of bed at 30 degrees and not lying on the operative side; 2) monitoring the scalp at the craniectomy site for a "boggy" appearance – oedema which is expected in the initial post – operative period, due to CSF recirculation & wound healing; 3) assessing pain and giving analgesia; 4) meticulous wound care and checking daily for signs of infection; 5) checking other surgical wound sites; 6) consulting with physiotherapy regarding the provision of a helmet to protect Mary's brain until cranioplasty was performed 7) communicating with Mary in terms she could understand and ongoing communication with the family.

Progress during treatment on the neurology ward:

Although Mary progressed well, she experienced complications. She had some partial facial seizure activity which was controlled by the antiepileptic medication, Sodium Valproate. Her liver function tests were elevated (thought to be an unwanted effect of the statin medication and paracetamol) and improved after withholding the statin and only administering paracetamol when required. Mary experienced hallucinations; the contributing factors were likely to be medication and illness-related but this was never clearly elucidated. Nocturnal temazepam was given and the symptoms subsided. In addition, she had constipation resulting in overflow diarrhoea and abdominal pain which resolved after a fleet enema and regular aperients.

Mary was reviewed by the rehabilitation team and enrolled in Stroke Acute Rehabilitation Therapy (START). She responded well to rehabilitation walking independently and managing to perform activities of daily living such as showering, dressing and cooking with minimal assistance.

Cranioplasty (bone was reinserted in her cranium) was performed 6 weeks after her craniectomy and the wound healed well. Mary's function improved and she was discharged home with few symptoms or deficits aside from mild left sided weakness and cognitive impairment.

Conclusion

This paper summarises the treatment journey for Mary, a 62 year old female who presented to our facility with MMCAI and the effectiveness of both thrombolysis and ECR in improving outcomes for patients who experience ischaemic stroke. Our examination of the evidence suggests that although life saving the functional outcome for DC varies and QoL differs. Our case report highlights the complexity in managing patients who experience MMCAI. It highlights the vital role the neuro critical care nurse specialist played in not only assessing, monitoring and treating Mary but also facilitating discussions and providing information and advice to her and her family prior to making the important decision to undergo DC.

Acknowledgement:

The authors acknowledge the generosity of 'Mary' and her family in providing permission to write about Mary's treatment in our facility.

Conflict of interest:
The authors declare that they have no conflicts of interest.

References :

Back, L., Nagaraja, V., Kapur, A., & Eslick, G. D. (2015). Role of decompressive hemicraniectomy in extensive middle cerebral artery strokes: a meta-analysis of randomised trials. Internal Medicine Journal, 45(7), 711-717. doi:10.1111/imj.12724

Badenes, R., Prisco, L., Maruenda, A., & Taccone, F. S. (2017). Criteria for Intensive Care admission and monitoring after elective craniotomy. Curr Opin Anaesthesiol. doi:10.1097/ACO.0000000000000503

Bose, G., & Luoma, A. M. V. (2017). Postoperative care of neurosurgical patients: general principles. Anaesthesia & Intensive Care Medicine, 18(6), 296-303. doi:https://doi.org/10.1016/j.mpaic.2017.03.004

Brott, T., Adams, H. P., Jr., Olinger, C. P., Marler, J. R., Barsan, W. G., Biller, J., . . . et al. (1989). Measurements of acute cerebral infarction: a clinical examination scale. Stroke, 20(7), 864-870.

Emberson, J., Lees, K. R., Lyden, P., Blackwell, L., Albers, G., Bluhmki, E., . . . Hacke, W. (2014). Effect of treatment delay, age, and stroke severity on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: a meta-analysis of individual patient data from randomised trials. The Lancet, 384(9958), 1929-1935. doi:http://dx.doi.org/10.1016/S0140-6736(14)60584-5

Goyal, M., Menon, B. K., van Zwam, W. H., Dippel, D. W. J., Mitchell, P. J., Demchuk, A. M., . . . Jovin, T. G. (2016). Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. The Lancet, 387(10029), 1723-1731. doi:https://doi.org/10.1016/S0140-6736(16)00163-X

Green, T., Demchuk, A., & Newcommon, N. (2015). Aggressive surgical interventions for severe stroke: Impact on quality of life, caregiver burden and family outcomes. Canadian Journal of Neuroscience Nursing, 37(2), 15-25.

Hacke, W., Kaste, M., Bluhmki, E., Brozman, M., Davalos, A., Guidetti, D., . . . Investigators, E. (2008). Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. N Engl J Med, 359(13), 1317-1329. doi:10.1056/NEJMoa0804656

Hacke, W., Schwab, S., Horn, M., Spranger, M., De Georgia, M., & von Kummer, R. (1996). 'Malignant' middle cerebral artery territory infarction: clinical course and prognostic signs. Arch Neurol, 53(4), 309-315.

Huttner, H. B., & Schwab, S. (2009). Malignant middle cerebral artery infarction: clinical characteristics, treatment strategies, and future perspectives. The Lancet Neurology., 8 (10), 949-958.

Lambrinos, A., Schaink, A. K., Dhalla, I., Krings, T., Casaubon, L. K., Sikich, N., . . . Hill , M. D. (2016). Mechanical Thrombectomy in Acute Ischemic Stroke: A Systematic Review. Canadian Journal of Neurological Sciences, 43(4), 455-460. doi:10.1017/cjn.2016.30

Liddle, C. (2013). Principles of monitoring postoperative patients. Nurs Times, 109(22), 24-26.

McCormack, B. (2003). A conceptual framework for person-centred practice with older people. Int J Nurs Pract, 9(3), 202-209.

McKenna, A., Wilson, C. F., Caldwell, S. B., & Curran, D. (2012). Functional outcomes of decompressive hemicraniectomy following malignant middle cerebral artery infarctions: a systematic review. British Journal Of Neurosurgery, 26(3), 310-315. doi:10.3109/02688697.2012.654835

Middelaar, T., Nederkoorn, P. J., Worp, H. B., Stam, J., & Richard, E. (2015). Quality of life after surgical decompression for space-occupying middle cerebral artery infarction: Systematic review. International Journal of Stroke, 10(2), 170-176. doi:10.1111/ijs.12329

Neugebauer, H., Fiss, I., Pinczolits, A., Hecht, N., Witsch, J., Dengler, N. F., . . . Woitzik, J. (2016). Large Size Hemicraniectomy Reduces Early Herniation in Malignant Middle Cerebral Artery Infarction. Cerebrovasc Dis, 41(5-6), 283-290. doi:10.1159/000443935

Nittby, H. R., Maltese, A., & Ståhl, N. (2016). Early postoperative haematomas in neurosurgery. Acta Neurochirurgica, 158(5), 837-846. doi:10.1007/s00701-016-2778-4

Nogueira, R. G., Jadhav, A. P., Haussen, D. C., Bonafe, A., Budzik, R. F., Bhuva, P., . . . Investigators, D. T. (2018). Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. N Engl J Med, 378 (1), 11-21. doi:10.1056/NEJMoa1706442

Northern Sydney Local Health District. (2009). Craniectomy post-operative management In. St Leonards NSW 2065 Australia

Nyquist, P., Bautista, C., Jichici, D., Burns, J., Chhangani, S., DeFilippis, M., . . . Meyer, K. (2016). Prophylaxis of Venous Thrombosis in Neurocritical Care Patients: An Evidence-Based Guideline: A Statement for Healthcare Professionals from the Neurocritical Care Society. Neurocrit Care, 24(1), 47-60. doi:10.1007/s12028-015-0221-y

Oppenheim, C., Samson, Y., Manai, R., Lalam, T., Vandamme, X., Crozier, S., . . . Marsault, C. (2000). Prediction of malignant middle cerebral artery infarction by diffusion-weighted imaging. Stroke, 31(9), 2175-2181.

Powers, W. J., Derdeyn, C. P., Biller, J., Coffey, C. S., Hoh, B. L., Jauch, E. C., . . . Yavagal, D. R. (2015). 2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients With Acute Ischemic Stroke Regarding Endovascular Treatment. A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association, 46(10), 3020-3035. doi:10.1161/str.0000000000000074

Powers, W. J., Rabinstein, A. A., Ackerson, T., Adeoye, O. M., Bambakidis, N. C., Becker, K., . . . Tirschwell, D. L. (2018). 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. doi:10.1161/str.0000000000000158

Rahme, R., Zuccarello, M., Kleindorfer, D., Adeoye, O. M., & Ringer, A. J. (2012). Decompressive hemicraniectomy for malignant middle cerebral artery territory infarction: is life worth living? Journal of Neurosurgery, 117(4), 749-754. doi:10.3171/2012.6.jns111140

Rankin, J. (1957). Cerebral vascular accidents in patients over the age of 60. II. Prognosis. Scott Med J, 2(5), 200-215. doi:10.1177/003693305700200504

Siegemund, M., & Steiner, L. A. (2015). Postoperative care of the neurosurgical patient. Curr Opin Anaesthesiol, 28(5), 487-493. doi:10.1097/ACO.0000000000000229

Streib, C. D., Hartman, L. M., & Molyneaux, B. J. (2016). Early decompressive craniectomy for malignant cerebral infarction. Neurology: Clinical Practice, 6(5), 433-443.

Stroke Foundation. (2017). Clinical Guidelines for Stroke Management.

Thomalla, G. J., Kucinski, T., Schoder, V., Fiehler, J., Knab, R., Zeumer, H., . . . Rother, J. (2003). Prediction of malignant middle cerebral artery infarction by early perfusion- and diffusion-weighted magnetic resonance imaging. Stroke, 34(8), 1892-1899. doi:10.1161/01.STR.0000081985.44625.B6

Treadwell, S., & Thanvi, B. (2010). Malignant middle cerebral artery (MCA) infarction: pathophysiology, diagnosis and management. Postgraduate Medical Journal, 86, 235-242.

Tsaousi, G. G., Pourzitaki, C., & Bilotta, F. (2017). Prophylaxis of postoperative complications after craniotomy. Curr Opin Anaesthesiol. doi:10.1097/ACO.0000000000000493

Vahedi, K., Hofmeijer, J., Juettler, E., Vicaut, E., George, B., Algra, A., . . . Hacke, W. (2007). Early decompressive surgery in malignant infarction of the middle cerebral artery: a pooled analysis of three randomised controlled trials. The Lancet Neurology, 6(3), 215-222. doi:http://dx.doi.org/10.1016/S1474-4422(07)70036-4

Vahedi, K., Vicaut, E., Mateo, J., Kurtz, A., Orabi, M., Guichard, J.-P., . . . Bousser, M.-G. (2007). Sequential-Design, Multicenter, Randomized, Controlled Trial of Early Decompressive Craniectomy in Malignant Middle Cerebral Artery Infarction (DECIMAL Trial). Stroke, 38(9), 2506-2517. doi:10.1161/strokeaha.107.485235

Wang, X., Zhou, Y. C., Zhu, W. D., Sun, Y., Fu, P., Lei, D. Q., & Zhao, H. Y. (2017). The risk of postoperative hemorrhage and efficacy of heparin for preventing deep vein thrombosis and pulmonary embolism in adult patients undergoing neurosurgery: a systematic review and meta-analysis. J Investig Med. doi:10.1136/jim-2016-000235

Wardlaw, J. M., Murray, V., Berge, E., & del Zoppo, G. J. (2014). Thrombolysis for acute ischaemic stroke. Cochrane Database of Systematic Reviews(7). doi:10.1002/14651858.CD000213.pub3