HYPOTHERMIC CIRCULATORY ARREST (HCA)

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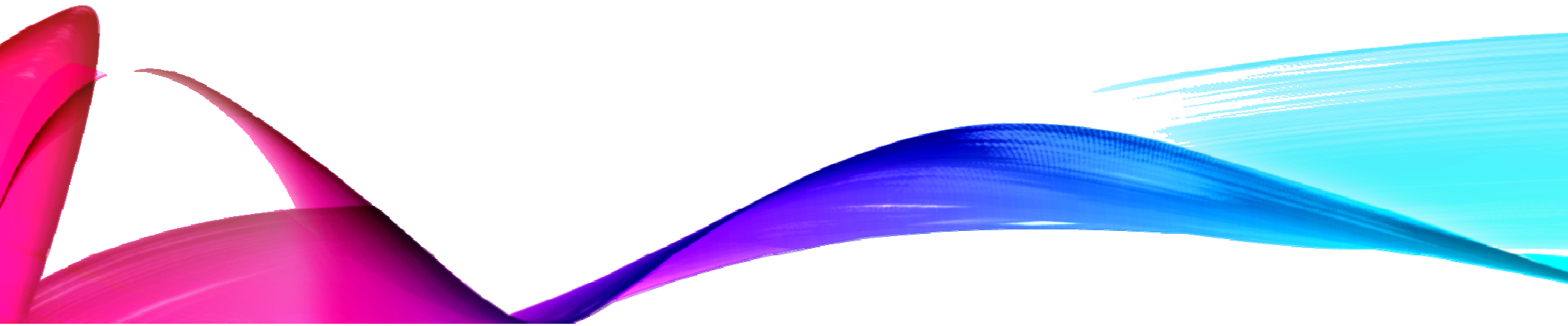
BASIC PRINCIPLES



•HCA

- the use of systemic hypothermia to protect the brain and visceral organs during the ischemic period,
- provides a bloodless operative field to facilitate arch reconstruction.

- **“HCA alone”.**

HCA without adjunctive cerebral perfusion

- **the two levels of HCA**

1. Deep hypothermic circulatory arrest (DHCA)
2. moderate hypothermic circulatory arrest (MHCA)

HYPOTHERMIA CLASSIFICATIONS IN AORTIC ARCH SURGERY

	Nasopharyngeal temperature
Profound عميق جدا hypothermia	≤14°C
Deep hypothermia	14.1-20°C
Moderate hypothermia	20.1-28°C
Mild hypothermia	28.1-34°C

CEREBRAL BLOOD FLOW & METABOLISM

physiology

- **The brain**

➢depends upon the aerobic process of glycolysis for energy

➢intolerant of ischemia

➢in the setting of ischemia quickly resorts يلجأ to anaerobic metabolism

- The metabolic rate of the brain are approximately **7.5 times** the metabolism of non-nervous tissues.
- The autoregulatory capacityقدرة of the cerebral microcirculation>>constant cerebral flow rates
- ratio of cerebral blood flow to metabolism of **20:1.**

- **In order to support the high cerebral metabolic rate,**

➢ the body provides approximately **60 mg** of glucose and **3.5 mL** of oxygen per **100 mg** of brain tissue per **minute.**

➢ Through cerebral blood flow of **750 to 900 mL/min or 15%** of resting cardiac output under **normothermic** conditions.

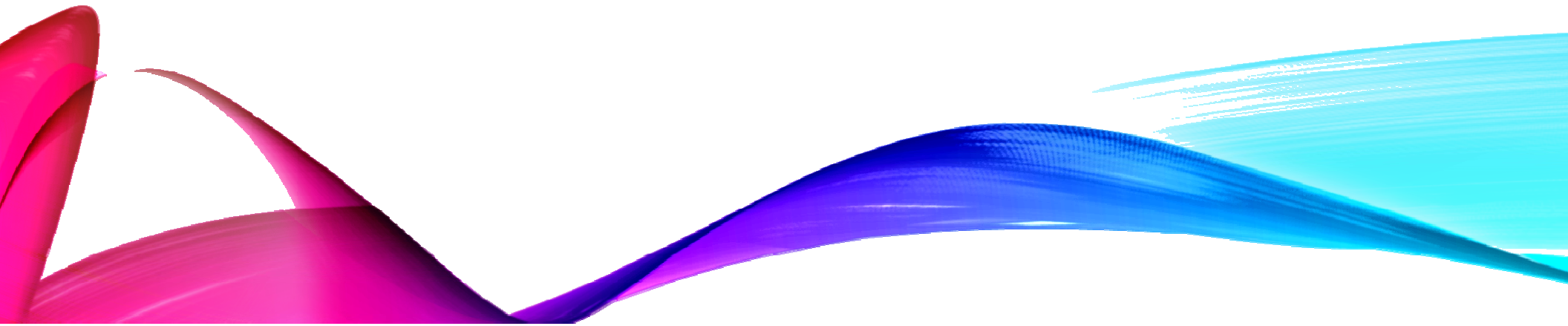
physiologic variables can modulatتؤثر cerebral blood flow

1. temperature,
2. pH,
3. hematocrit

- hypothermia
  - ➢ reduces **cerebral blood flow** in a linear fashion.
  - ➢ reduce **cerebral metabolism in a** exponential fashion

- EEG silence سكون كهربائية الدماغ
  - is a reliable and safe measure of maximal cerebral metabolic suppression.

PATHOGENESIS OF BRAIN INJURY DURING HCA



- two different types of brain injury during HCA:

(1) permanent neurologic dysfunction (PND)

(2) temporary neurologic dysfunction (TND).

- **PND:**
  - commonly referred to stroke,
  - Clinically as a focal neurologic deficit
  - Cause an embolism of particulate matter or air/gas bubbles
  - Risk factors

atheromatous disease involving both the ascending aortic and the site of arterial cannulation.

•TND

- global cerebral ischemic injury
- CAUSE inadequate cerebral protection.
- results in necrotic and/or apoptotic neuronal cell death
- Brain imaging with computed tomography or magnetic resonance imaging is negative.

- Patients with TND can experience

1.confusion,تخليط

2.poor cognitionضعف الادراك,

3.altered short-term memoryتبدل الذاكره قصيرة الامد,

4.fine motor deficitsعيوب حركيه خفيفه.

5. agitation, هياج

6.delirium,هذيان

7.prolonged obtundationتبلد احساس,

8.parkinsonism باركنسونيه

9.without localizing signs in the immediate postoperative period.

- **Necrotic cell death**

➢Risk factors

1. inadequate levels of hypothermia,
2. the presence of electrocerebral activity at the time of circulatory arrest,
3. prolonged duration (>40 minutes) of HCA without cerebral perfusion.

Apototic cell death

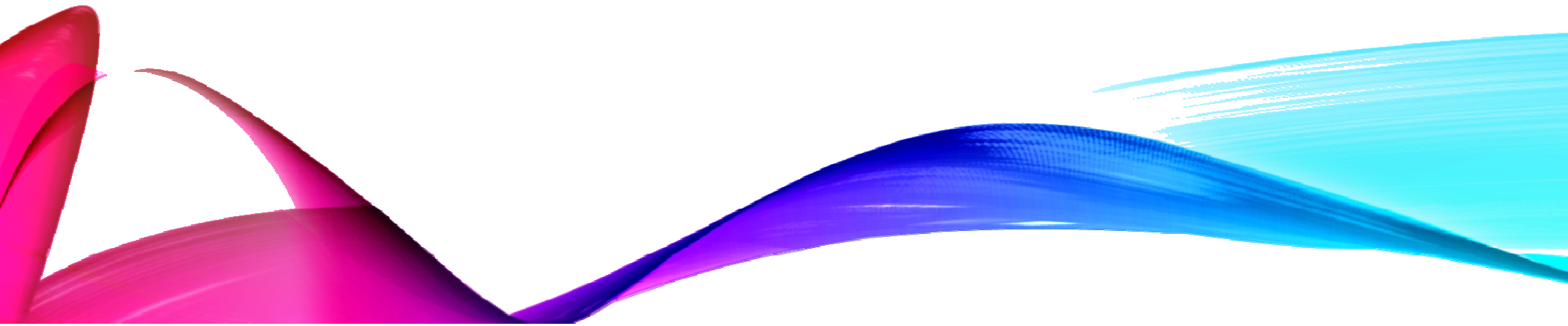
- The second type of cell death observed in patients after HCA
- it is a carefully regulated process
- is an energy-dependent process that occurs despite adequate stores of cellular energy.
- Multiple animal models have demonstrated

apoptotic cell death beginning within hours of reperfusion and continuing as long as **72 hours** after DHCA.

- foci with high metabolic rates are more sensitive to ischemia.

1. hippocampus, الحصين
2. basal ganglia العقد القاعديه
3. cerebellum.مخيخ

COOLING



- A temperature gradient (arterial inflow to venous return)

✓ does not exceed 10°C during the cooling period

to prevent the formation of gaseous emboli.

- The duration of the cooling is dependent upon

1.blood flow,

2. temperature gradient (between perfusate سائل الارواء and organs),

3.tissue-specific coefficients of temperature exchange معامل تغير الحراره.

- Patient-specific variables that impact cooling

1. vascular disease
2. body mass index.

- Temperature is monitored in many different sites including

1.the inflow and outflow lines of the perfusion circuit,

2. by probes inserted into the bladder, rectum, nasopharynx, and esophagus.

- If the strategy is HCA alone or in conjunction with RCP, >>>>

esophageal or nasopharyngeal temperatures, are more important,

as these sites have been shown to closely approximate brain temperature.

- if antegrade cerebral perfusion is used,>>>> bladder or rectal temperatures are more important,

as visceral organ protection becomes the primary goal of hypothermia.

during the cooling period.

We are monitoring

1.time,

2.temperature,

3.oxygen saturation in jugular venous bulb ,

4.electroencephalographic activity

- accepted parameters that ensure sufficient cerebral metabolic suppression

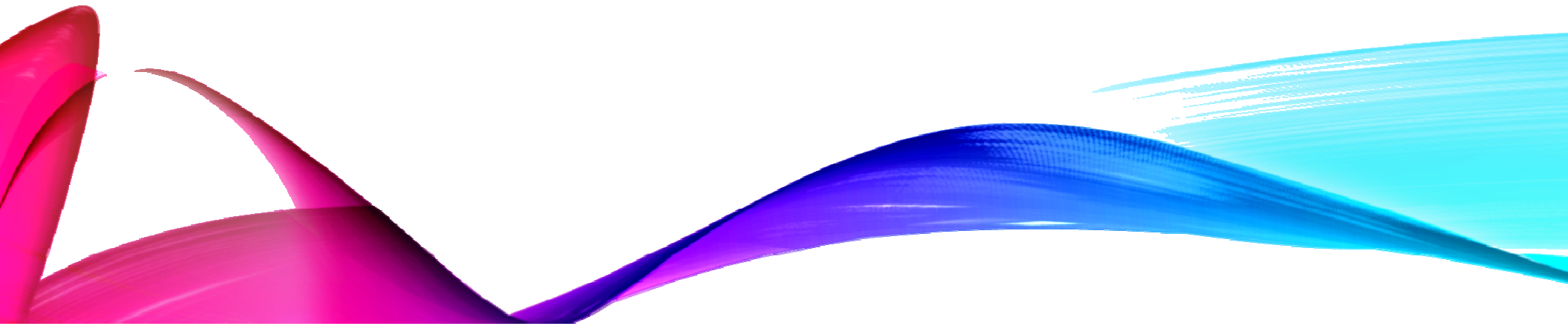
1. cooling for a minimum of **30 minutes**,
2. a goal nasopharyngeal temperature of **18°C,**
3. a jugular venous saturation **> 95%,**
4. electrocerebral silence**سكون دماغي كهربائي.**

➢ However, relying**الاعتماد** on such parameters alone may not be completely adequate.

- study
- >50% of patients had not achieved electrocerebral silence لم يحققو السكون الدماغي الكهربائيat a nasopharyngeal temperature of 18°C,
- approximately 25% of patients have not achieved electrocerebral silence after 30 minutes of cooling.
- This emphasizes the need to evaluate all available monitoring parameters prior to initiating HCA.

- If HCA alone is employed, >>>>topical cooling by packing the head in ice is advocated >>>>in order to minimize upward driftالانزياح of intracranial temperatures during the ischemic period.

REWARMING



- is a critical phase
- can exacerbate neuronal injury if not conducted properly.

- Following HCA, reinitiating brain reperfusion with a short period of low-pressure cold blood flow prior to rewarming is recommended.
- ينصح بالبدء بتروية الدماغ بدم بارد منخفض الضغط لفتره قصيره قبل البدء باعادة التدفئه

- cold reperfusion has been associated with

➢improved cerebral perfusion,

➢a reduction in intracranial pressure,

➢ a decrease in cerebral edema.

➢attenuatesتضعف the adverse effects of the impaired cerebral vascular autoregulation that occurs following DHCA>>>>>>a reduction in brain injury.

- reperfusion should be made with a higher hematocrit and normoglycemia.
- A lower hematocrit in the reperfusate (≈20%) >>>>increase the degree of histopathologic brain injury

- a higher hematocrit is beneficial due to

1.an increased oxygen carrying capacity,

2.an increase in the free-radical الجذور الحرة scavenging كسح capacity قدرة.

- Hyperglycemia during reperfusion >>>>>>worsening intracellular acidosis, which prevents the return of normal cellular metabolism.

- Cerebral vascular resistance is increased for up to **8 hours** following HCA.

>>>>>a reduction in cerebral blood flow

➢During this period>>>> secondary brain injury can occur with episodes of hypotension, hypoxemia, and anemia.

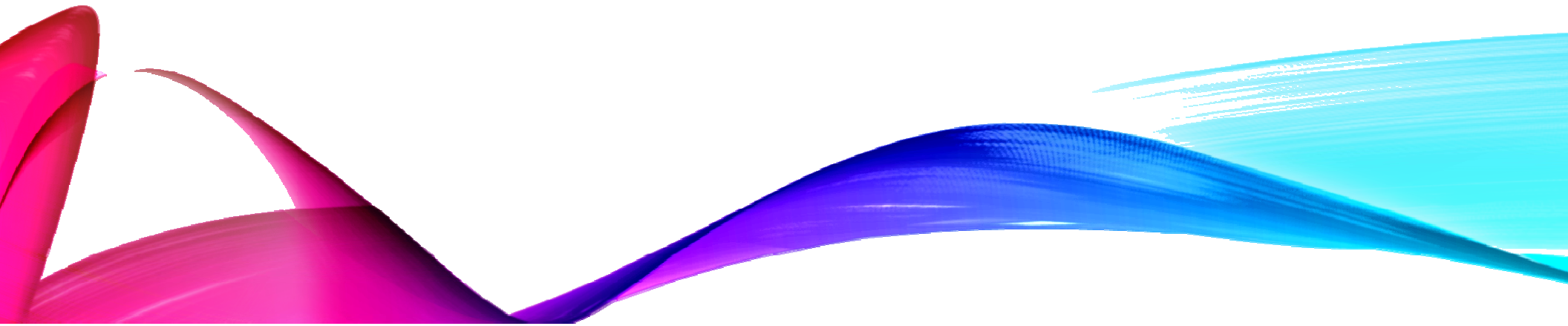
- the temperature of the perfusate should not exceed **36°C**.
- Cerebral hyperthermia results in

1.worse neurobehavioral outcomes

2. increased neuronal cell injury

➢ The mechanisms increases in the permeabilityنفاذية of the blood-brain barrier and cellular metabolism

SAFE DURATION OF HCA



Temperature (°C)	Cerebral metabolic rate (% of base line)	Safe duration of HCA (min)
٣٧	100	5
٣٠	56 (52-60)	9 (8-10)
٢٥	37 (33-42)	14 (12-15)
٢٠	24 (21-29)	21 (17-24)
١٥	16 (13-20)	31 (25-38)
١٠	11 (8-4)	45 (36-62)

- "DHCA alone"

➢ is the strategy of choice for surgeons who infrequently perform aortic arch reconstructions.

➢ The main concern is the duration of the circulatory arrest.

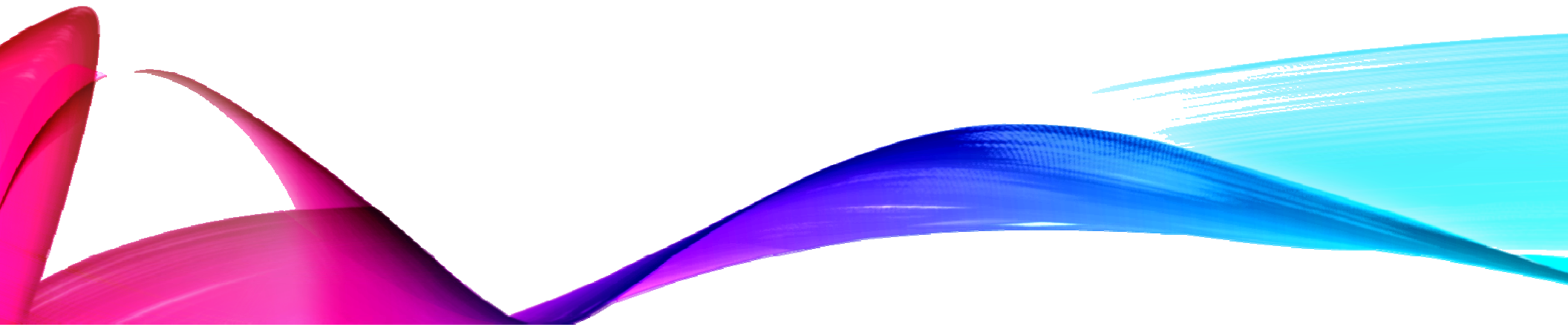
- when using DHCA alone >>>

➢cooling for **30 minutes** to achieve an esophageal/nasopharyngeal temperature of **15°C** >>>>will safely provide cerebral protection for **30 minutes** of circulatory arrest.

➢beyond this duration, adjunctive cerebral perfusion should be employed.

because there was a trend toward an increased stroke risk with a DHCA time exceeding **40 minutes**.

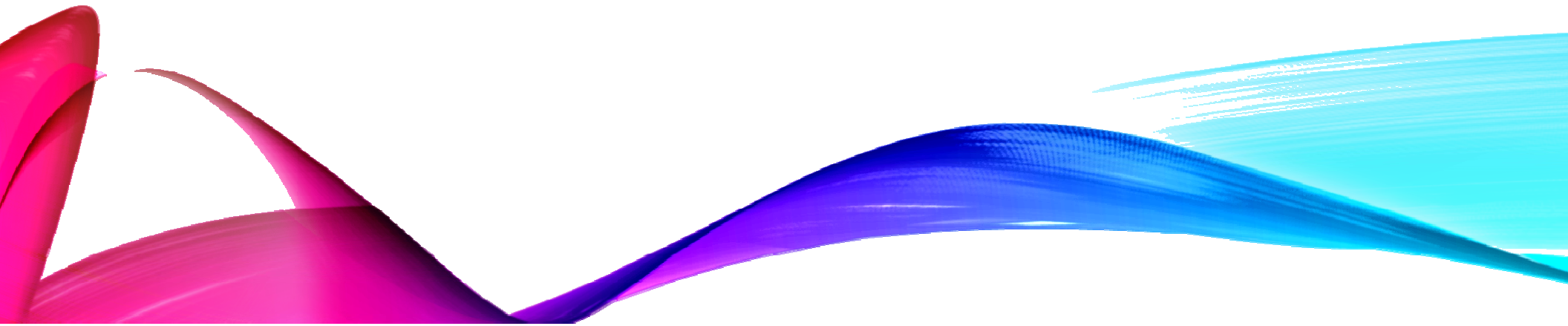
CEREBRAL PERFUSION



- TWO types

1. RETROGRADE CEREBRAL PERFUSION (RCP)
2. SELECTIVE ANTEGRADE CEREBRAL PERFUSION (SACP)

RETROGRADE CEREBRAL PERFUSION



- RCP is performed by

➢ cannulating the superior vena cava,

➢infusing hypothermic arterial blood up the superior vena cava (from the cardiopulmonary bypass circuit)

➢flow rates are **300 to 500 mL/min** to maintain a SVC pressure of **20 to 25 mm Hg.**

➢ to perfuse the brain in a retrograde direction (during the period of circulatory arrest)

➢produce dark blood from the origins of the great vessels into the open aortic arch during HCA.

- The theoretical benefits of RCP in cerebral protection are

(1) flush embolic material (gaseous and particulate) from the cerebral circulation;

(2) maintain cerebral hypothermia

(3) support cerebral metabolism

- Based upon human cadaver الجثه studies,

➢ the majority of internal jugular veins have competent venous valves.

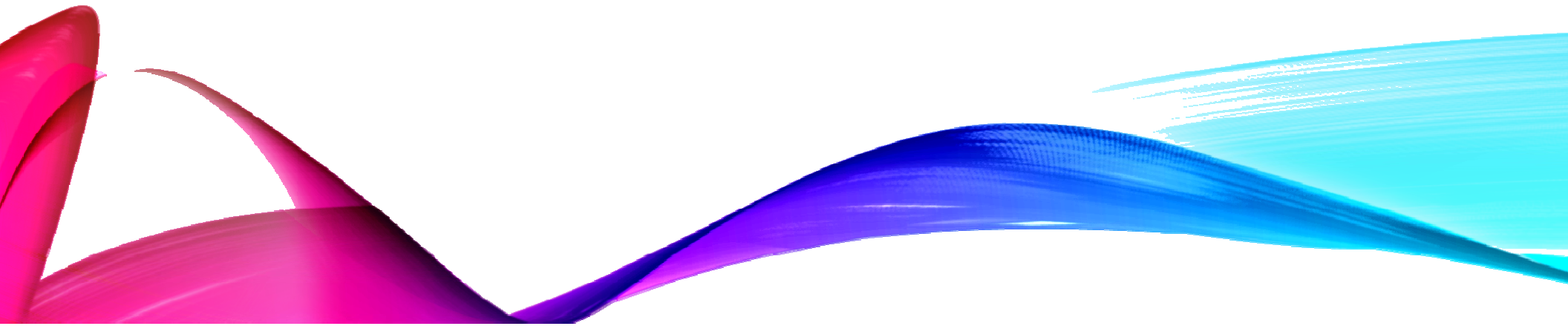
➢ significant retrograde cerebral blood flow was observed in <30% of cadavers,

➢ Cerebral blood flow can be improved with higher retrograde perfusion pressures and occlusion of the inferior vena cava; BUT there is an increase in cerebral edema with evidence of cerebral injury.

- Despite the unconvincing غير المقنعه results of the cerebral blood flow data, RCP has been shown to

1. improve metabolic support during HCA,
2. improved oxygen delivery,
3. increased levels of cerebral ATP,
4. a reduction in lactate production,
5. improved brain tissue oxygenation.
6. improved clinical outcomes
7. reduced mortality and stroke rates compared with DHCA alone

SELECTIVE ANTEGRADE CEREBRAL PERFUSION



- Circulatory arrest refers to the complete interruption of the circulation and the absence of perfusion to all organs.
- SACP changes this conceptالمفهوم from total body circulatory arrest to lower body circulatory arrest
- Therefore the legs and the abdominal visceral are the soleوحيده ischemic organs during the circulatory arrest period

- the ability of SACP to

1. provide adequate cerebral blood flow
2. maintenance of near normal cerebral metabolism
3. preserved cell structure
4. improved neurophysiologic recovery,

5.lower intracranial pressure,

6.less cerebral edema,

7.reduced tissue acidosis following the circulatory arrest period.

>>>> superiority of SACP compared to RCP during the period of HCA

- SACP techniques.
  - Bilateral SACP (bSACP)
  - unilateral SACP (uSACP)

- **Bilateral SACP (bSACP) involves**

➢ direct cannulation of the cervical left and right common carotid arteries

➢or perfusion cannulas into the ostia of the innominate and left carotid arteries via the open arch at the time of HCA.

➢The disadvantages of this latter method include

1.the risk of introducingانبعاث air or atherosclerotic emboli

2. clutteringتبعثر the operative field with additional cannulas.

- **unilateral SACP (uSACP)**
- technique

➢ An 8-mm graft is sewn end to side to the right axillary artery prior to sternotomy and used as the arterial inflow line to initiate cardiopulmonary bypass.

➢ At the time of HCA, blood flow is decreased to 10 mL/kg/min

➢ Flows are adjusted to maintain cerebral perfusion pressures of 50 to 60 mm Hg.

➢ the base of the innominate and left common carotid arteries are occluded with vascular clamps

- Left carotid occlusion is performed to pressurize يمارس ضغط the extra cranial circulation and collateral system and minimize steal.

>>>>>This enables blood to perfuse the brain and spinal cord.

- Criticsنقاد of this technique argue that uSACP provides insufficient cerebral blood flow to the left cerebral hemisphere.

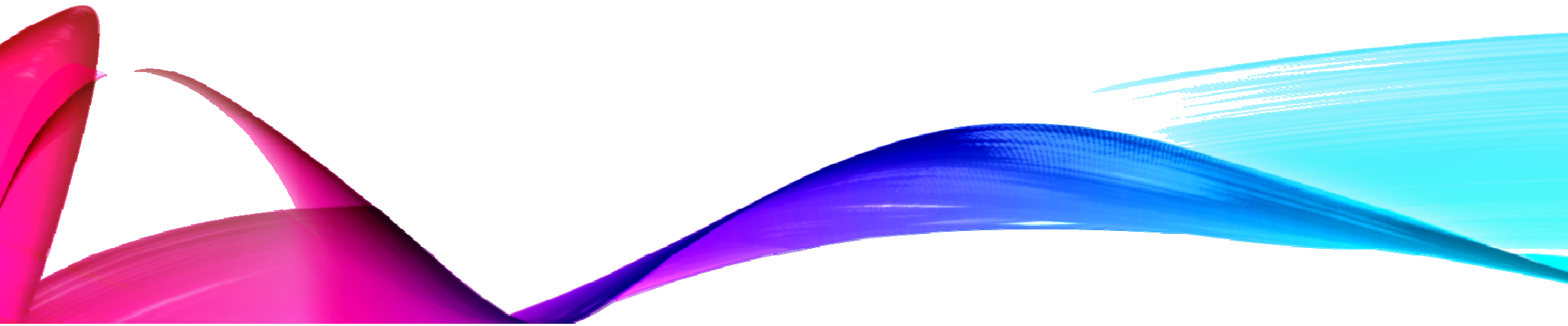
- studies

➢no difference in morbidity and mortality between uSACP and bSACP.

➢no significant difference in cerebral blood flow between uSACP and bSACP, with and without an intact circle of Willis.

- there was a trend toward a higher incidence of stroke in the bSACP group that was attributed to great vessel manipulation.
- the preferred method of cerebral perfusion is unilateral SACP (uSACP) via right axillary artery cannulation.

MODERATE HYPOTHERMIA



- the induction of deep hypothermia is not a benign process.
- It requires prolonged cardiopulmonary bypass times for cooling and rewarming which can have detrimentalضاره effects on the lungs, liver, and kidneys.

- Deep hypothermia has been associated with

1.vascular endothelial dysfunction,

2.bleeding complications,

3. an increased systemic inflammatory response.

- cardiopulmonary bypass time > 180 minutes and deep hypothermia were predictive risk factors for renal and/ or liver dysfunction.

- SACP has led to a departure الابتعاد from the use of deep hypothermia, to the use of moderate levels of hypothermia
- AS the visceral organs require a reduced degree of hypothermia for optimal protection and are more tolerant of ischemia.

- Comparing DHCA (<25°C)/ bSACP VS MHCA (>25°C)/bSACP.

➢There was no difference in mortality, PND, TND,

1.Their overall mortality was 4.7%

2. PND and TND rates of 3.5% and 6.7%, respectively,

➢There was no difference in

1.dialysis-dependent renal failure

2.liver dysfunction

•Hemiarch replacement

- ➢is routinely conducted at temperatures of 28 to 29°C
- • Mean circulatory arrest times
- ➢ 23 minutes in elective cases
- ➢33 minutes in emergent cases.
- ❑ with this technique.
- ➢mortality rates in elective and emergent cases of 4.3% and 7.7%, respectively.
- ➢low incidence of PND (elective 1.9%, emergent 4.6%),
- ➢TND (elective 3.8%, emergent 6.2%),
- ➢ dialysis-dependent renal failure (elective 2.4%, emergent 9.2%)

- **Total arch replacement**

➢is conducted at temperatures of 25 to 26°C for both emergent and elective cases.

➢The mean duration of circulatory arrest for these patients was 55 minutes.

➢operative mortality of 9.7%.

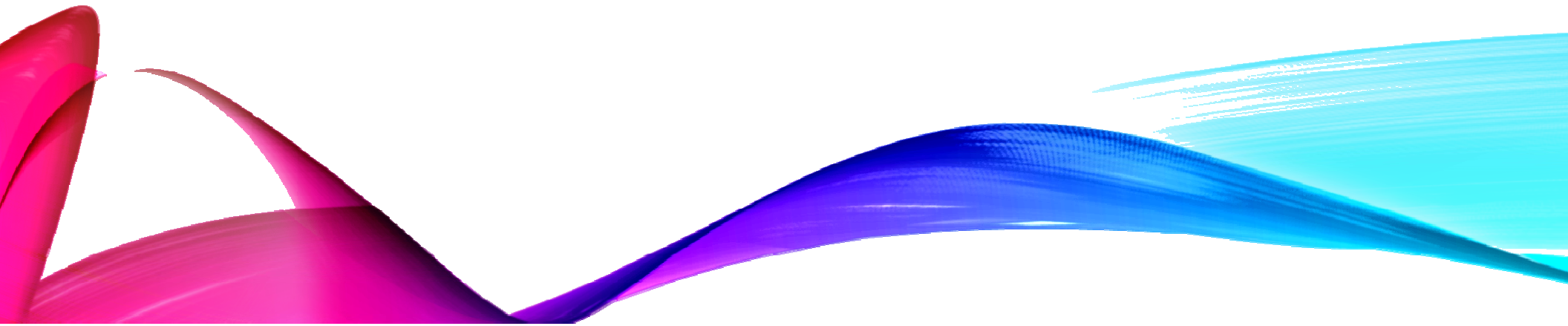
➢The incidence of PND, TND, 2.8%, 5.6%, respectively

➢ The incidence of dialysis-dependent renal failure were 2.8%,.

CONCLUSION

- MHCA/uSACP currently represents the safe and effective strategy in aortic arch surgery.

PHARMACOLOGIC ADJUNCTS



- to optimize cerebral protection during HCA
- Pharmacologic Adjuncts include

1.corticosteroids,

2.barbiturates,

3. mannitol.

- Cardiopulmonary bypass and DHCA have been associated with

1. a significant systemic inflammatory response,
2. increased permeabilityنفوذية of the bloodbrain barrier and cerebral edema.

- **Corticosteroids**

➢suppress the inflammatory response associated with DHCA.

➢pretreatment with corticosteroids prior to cardiopulmonary bypass

1.reduces the permeability of the blood-brain barrier,

2.attenuates يضعف cerebral apoptosis

3.improves cerebral blood flow following DHCA.

➢our typical protocol includes the administration of 1 g of methylprednisolone following induction of anesthesia and a rapid taper of steroids over the first 72 hours of the postoperative period.

- Barbiturates

➢reduce cerebral oxygen consumption,

➢minimize cerebral edema.

- Thiopental, the most commonly used in cases requiring DHCA.

- The timing and dose of thiopental administration can impact its effectiveness
  - thiopental is administered during HCA.
  - If administered prior to HCA, the cerebral energy state is reduced which may lead to adverse outcomes;

- there is also a dose-dependent effect of barbiturates

➢ low-dose barbiturates minimize cerebral metabolism,

➢ higher doses are associated with negative inotropy and sedation which could prolong the time to extubation.

- A recent analysis of the currently existing data did not conclusively demonstrate a cerebral protection advantage with the use of barbiturates in patients undergoing DHCA.

- **Mannitol**

➢is a potentفعال osmotic diuretic

➢reducing cerebral edema.

➢ It also possesses free oxygen radical scavenger properties

➢ may have an anti-apoptotic effect following cerebral ischemia.

- In summary, the use of steroids and mannitol is advantageous following DHCA, while the use of thiopental cannot be recommended based upon the available data.