Attachment 1: Tables and schemes

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### Table 1: Evidence based recommendations: basic monitoring

| Basic monitoring                                                                                                                                  | Evidence grade | Grade of recommendation |
|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------------|
| For continuous ECG-monitoring for the diagnosis of arrhythmias and ischemia leads II and V5, or alternatively II and V3, or II and V4, or when technologically possible V3, V4 and V5 should be used. | C              | A                        |
| ST-segment monitoring can be used with any ECG monitoring.                                                                                         | D              | 0                        |
| For intensive care patients a 12 channel ECG on admission and daily for the first three post operative days of ICU stay might be documented. After the 3rd day of ICU treatment, the indication depends on the individual clinical situation. | D              | B                        |
| Continuous monitoring with pulse oximetry detects clinically inapparent O₂-desaturations and should therefore be used as continuous monitoring method.         | A              | A                        |
| Continuous invasive blood pressure monitoring should be obligatory following cardiac surgery, as non-invasive measurement is discontinuous and too imprecise. | B              | A                        |
| The CVP can, despite methodological limitations, provide important information regarding acute changes in right ventricular compliance and/or the volume status and thus might be measured continuously. | D              | B                        |
| Temperature might be measured continuously. If measured discontinuously, it might be taken and recorded 4 hourly.                                                                 | D              | B                        |
| The fluid balance might be recorded hourly for the first 24 hours, thereafter dependent on the clinical status of the patient, 4 hourly.                    | D              | B                        |
| An ABG might be taken within 30 minutes of admission to the ICU, or during a period of cardiopulmonary instability or following a change in the ventilation setting. When the FiO₂ is ≥ 0.6 an AGB might be done 4 hourly, otherwise, it is recommended at least 8 hourly. | D              | B                        |
| ScvO₂ appropriately tracks the course of SvO₂ and can be used as an alternative. However, it should be borne in mind that a normal ScvO₂ is not necessarily proof for a normal SvO₂. | D              | 0                        |
Table 2: Evidence based recommendations for advanced haemodynamic monitoring: echocardiography

| Advanced hemodynamic monitoring: echocardiography | Evidence grade | Grade of recommendation |
|--------------------------------------------------|----------------|-------------------------|
| In patients who show acute persistent hemodynamic disturbances, do not respond to initial therapies, and demonstrate unclear ventricular dysfunction and determinants thereof, echocardiography is recommended for establishing diagnosis in the perioperative period and improves clinical outcome. | D | B |
| In comparison with TTE, TEE has diagnostic advantages particularly in ventilated post operative patients and can be used preferentially in this patient group. | D | 0 |
| Use of TEE in the perioperative period can improve clinical outcome in patients at increased risk of myocardial ischemia or infarction. | D | 0 |
| Assessing cardiac output with echocardiography using the Doppler method is just as reliable as the thermodilution techniques and is recommended to be used as an alternative to measuring CO discontinuously. | B | B |
| The TTE or TEE examination should be documented. | D | A |

Table 3: Evidence based recommendations: extended hemodynamic monitoring: transpulmonary thermodilution and pulse contour analysis

| Extended hemodynamic monitoring: transpulmonary thermodilution and pulse contour analysis | Evidence grade | Grade of recommendation |
|--------------------------------------------------------------------------------------|----------------|-------------------------|
| The pulse contour analysis in post operative cardiac surgery patients (CABG) shows good correlation with the gold standard method of pulmonary arterial thermodilution and might be used for extended hemodynamic monitoring. | C | B |
| The measurement of ITBV seems to be superior to the CVP and the PAOP from the PAC for the appraisal of cardiac preload. | C | 0 |
| When taking into account the methodologically intrinsic limitations, the parameters stroke volume variation (SVV) and pulse pressure variation (PPV) are superior to the central venous pressure (CVP) and the pulmonary artery occlusion pressure (PAOP) for predicting volume responsiveness. SVV and PPV therefore might be used as helpful supplement to hemodynamic diagnostics. | C | B |
Table 4: Evidence based recommendations: extended hemodynamic monitoring: pulmonary artery catheter

| Extended haemodynamic monitoring: pulmonary artery catheter | Evidence grade | Grade of recommendation |
|-----------------------------------------------------------|----------------|-------------------------|
| The PAC in cardiac surgical patients with low perioperative risks might not be used. | C              | B                       |
| The PAC can be used;                                       |                |                         |
| • for determining the cause and guiding therapy in severe LCOS | D              | 0                       |
| • for differentiating between left or right ventricular dysfunction |                |                         |
| • for diagnosis and orientation of therapy of pulmonary hypertension |                |                         |
| • in high risk cardiac surgery patients undergoing complex interventions |                |                         |

Abbreviation: LCOS=low cardiac output syndrome

Table 5: Evidence based recommendations: volume management

| Volume management | Evidence grade | Grade of recommendation |
|-------------------|----------------|-------------------------|
| When using crystalloid solutions balanced full electrolyte solutions can be favoured. | D              | 0                       |
| An advantage for hypertonic crystalloid solutions in comparison with isotonic or approximately equivalent isotonic crystalloid solutions has not been demonstrated. | A-             | 0                       |
| As artificial colloids, medium molecular weight HAES (6%) or succinylated gelatin can be recommended. | D              | 0                       |
| For volume replacement in cardiac surgical patients HAES can be used as well as human albumin. There is no scientific evidence to support the use of the more expensive albumin over medium molecular weight HAES (6%) preparations. | D              | 0                       |

Table 6: Evidence based recommendations: postoperative cardiocirculatory dysfunction

| Postoperative cardiovascular dysfunction | Evidence grade | Grade of recommendation |
|------------------------------------------|----------------|-------------------------|
| Preoperative or early postoperative administration of antiarrhythmics can be performed according to existing guidelines. | D              | 0                       |
| For assessment of acute volume responsiveness, passive leg raising should be performed prior to volume loading. | B              | A                       |

Attachment 1 to: Carl M, et al. S3 guidelines for intensive care in cardiac surgery patients: hemodynamic monitoring and cardiocirculatory system. GMS Ger Med Sci. 2010;8:Doc12. DOI: 10.3205/000101.
Table 7: Evidence based recommendations: left heart failure

| Left heart failure                                                                 | Evidence grade | Grade of recommendation |
|------------------------------------------------------------------------------------|----------------|-------------------------|
| Preload optimisation should be the basic prerequisite for medicinal or technical therapy of left heart failure. | D              | A                       |
| If goals are not reached after preload optimization, therapy with positive inotropes might be indicated. The choice of substance depends on the patient's specific situation. | D              | B                       |
| PDE III inhibitors can be preferred in patients who are on β-blockers and/or those who demonstrate inadequate hemodynamic response to dobutamine. | C              | C                       |
| For decreasing pre- and afterload in acute cardiac failure, treatment with nitrates might be indicated. | B              | B                       |
| If vasopressors are indicated, norepinephrine should be used as the only approved vasopressor. | C              | A                       |
| Dopamine for prophylaxis or therapy of renal failure is obsolete and should not be used. | A              | A                       |
| The protective effects of dopexamine for the hepatosplanchic perfusion and the increase in creatinine clearance is not proven in cardiac surgical patients. The administration of dopexamine might be not recommended. | A              | B                       |
| Levosimendan can be used for prevention and/or therapy of post-CPB LCOS, especially in high-risk patients with a reduced LVEF < 30%. A continuous infusion Dose of 0.1 µg/kgKG/min with a length of infusion of 24 h is recommended. A bolus dose should not be given. | B              | 0                       |

Table 8: Evidence based recommendations: right heart failure

| Right heart failure                                                                 | Evidence grade | Grade of recommendation |
|------------------------------------------------------------------------------------|----------------|-------------------------|
| For therapy of right heart failure with adequate coronary perfusion pressure, dobutamine, PDE III inhibitor or nitroglyceride are first choice. With insufficient perfusion pressure the additional use of norepinephrine might be indicated. When this is insufficient, additional treatment with epinephrine might be considered. | D              | B                       |
| Inhalative vasodilators (NO, prostanoids) might be indicated in therapy resistant right heart insufficiency. | D              | B                       |

Table 9: Evidence based recommendations: Intraaotic balloon counterpulsation

| IABP                                                                 | Evidence grade | Grade of recommendation |
|----------------------------------------------------------------------|----------------|-------------------------|
| The early use of IABP should be initiated when there is concomitant LCOS, an ischemia or an incomplete coronary revascularisation without the option of surgical intervention. | D              | A                       |

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**Scheme 1: Algorithm basic monitoring**

**Algorithm for basic monitoring**

- **ECG**
  - Continuously II and V5 (alternatively II and V3, II and V4 or V3, V4 and V5) with ST elevation analysis
  - Documented 12 lead ECG on admission to ICU and once daily for first 3 postop days, thereafter depending on the clinical situation

- **Pulse oximetry**
  - General indication

- **Capnography**
  - Optional indication for ventilated patients

- **IBP**
  - Continuously or at least 4 hourly intervals

- **CVP**
  - Hourly in the first 24 hrs, thereafter at 4 hourly intervals

- **Temperature measurement**
  - Within 30 mins in case of haemodynamic instability

- **Fluid balance**
  - Every 4hrs if FID2 < 0.6

- **ABG on ICU admission**
  - Every 8hrs or after change of therapy

- **ScvO2**

**Scheme 2: Algorithm for indications of advanced hemodynamic monitoring**

**Algorithm for indications for advanced hemodynamic monitoring**

- **Haemodynamic instability with ST-elevation**

- **LCOS postoperatively, high-risk cardiac surgery patients**

- **Valvular defect plus coronary heart disease and/or pulmonary hypertension, right heart failure**

- **TEE in intubated patients / TTE in extubated patients, 12 lead ECG, ScvO2**

- **TEE in intubated patients TTE in extubated patients ScvO2**
  - Pulse contour analysis
  - PAC in the case of RHF/LCOS

- **TEE in intubated patients / TTE in extubated patients PAC with continuous SvO2 monitoring**

Attachment 1 to: Carl M, et al. S3 guidelines for intensive care in cardiac surgery patients: hemodynamic monitoring and cardiocirculatory system. GMS Ger Med Sci. 2010;8:Doc12. DOI: 10.3205/000101.
Scheme 3: Algorithm postoperative volume therapy

**Algorithm for postoperative volume therapy**

- **Crystalloids**
  - Preferred use of balanced electrolyte solutions

- **Colloids**
  - Postoperative dose limitation for HES derivatives (excluding bleeding)
  - No postoperative dose limitations for gelatine derivatives

**Goal Values**

- $\text{ScvO}_2 > 70\%$ or $\text{SvO}_2 > 65\%$
- $\text{MAP} > 65\text{mmHg}$
- $\text{CI} > 2.0 \text{l/min/m}^2$
- $\text{CVP} 8-12 \text{mmHg}$
  (depending on ventilation)
- $\text{LVEDAI} (6-9 \text{cm}^2/\text{m}^2)$
- $\text{ITBVI} 850 - 1000 \text{ml/m}^2$
- $\text{GEDVI} 640 - 800 \text{ml/m}^2$
- $\text{PAOP} 12-15 \text{mmHg}$
- $\text{Diuresis} \geq 0.5 \text{ml/kgBW/h}$
- $\text{Lactate} < 3.0 \text{mmol/l}$

Attachment 1 to: Carl M, et al. S3 guidelines for intensive care in cardiac surgery patients: hemodynamic monitoring and cardiovirculary system. GMS Ger Med Sci. 2010;8:Doc12. DOI: 10.3205/000101.
Scheme 4: Algorithm for post operative cardiocirculatory dysfunction

**Algorithm for postoperative cardiovascular dysfunction**

- **Existence of at least two of the following criteria**
  - ScvO2 < 60% with SaO2 98%
  - Mean arterial pressure < 60 mmHg
  - Urine output < 0.5 ml/kgBW/h
  - Lactate > 2.0 mmol/l
  - Signs of peripheral vasoconstriction and hypotension

- **Passive leg raising** (delta pulse pressure)

- **Haemodynamic stabilisation / therapy evaluation with goal criteria**
  - HR < 60/min Pacemaker preferred, where appropriate positive chronotropic substances
  - ScvO2 > 70%
  - MAP > 65 mmHg
  - Urine volume > 0.5 ml/kgBW/h
  - CVP 8-12 mmHg

- **Remains hemodynamically unstable**

- **Haemodynamic stabilisation / therapy evaluation with goal criteria**
  - ScvO2 > 70%
  - MAP > 65 mmHg
  - Urine volume > 0.5 ml/kgBW/h
  - CVP 8-12 mmHg

- **Diagnosis? Surgical intervention possible?**

- **Tamponade**
- **LHF**
- **RHF**
- **LHF + RHF**

**Monitoring**
- Echocardiography
- Intermittent ScvO2
- 12 lead ECG
- Lactate
- Urine volume

**Attachment 1 to: Carl M, et al. S3 guidelines for intensive care in cardiac surgery patients: hemodynamic monitoring and cardiocirculatory system. GMS Ger Med Sci. 2010;8:Doc12. DOI: 10.3205/000101.**
Scheme 5: Algorithm for left heart failure

Advanced hemodynamic monitoring
TEE/PAC/pulse contour analysis

LVEDAI < 5cm2/m2
PAOP < 5mmHg
ITBVI < 750 ml/m2

Preload optimisation

LVEDAI < 7cm2/m2
PAOP < 10mmHg
ITBVI < 850 ml/m2

Volume challenge
1. Dobutamine or PDE-inhibitor
2. Epinephrine
Dobutamine ± Norepinephrine, PDE-inhibitor ± Norepinephrine

LVEDAI < 9cm2/m2
PAOP < 15mmHg
ITBVI < 1000 ml/m2

Inotrope increase
1. Dobutamine or PDE-inhibitor
2. Epinephrine
3. Levosimendan
Dobutamine ± Norepinephrine, PDE-inhibitor ± Norepinephrine

LVEDAI < 11cm2/m2
PAOP < 20mmHg
ITBVI < 1200 ml/m2

Preload reduction
Inotrope increase

1. Epinephrine plus PDE-inhibitor
2. Levosimendan
If necessary careful fluid removal

Goal values
ScvO2 > 70% or Svo2 > 65%,
MAP > 65 mmHg,
CI > 2.0 l/min,
CVP 8-12 mmHg,
(depending on ventilation),
LVEDAI 6-9 cm2/m2,
ITBVI 850-1000 ml/m2,
GEDVI 640-800 ml/m2,
PAOP 12-15 mmHg,
Diuresis > 0.5 ml/kg/BW/h,
Lactate < 3 mmol/l

IABP / Assist-device
Surgical intervention
Optimisation of therapies possible?
No
Goal values reached?
Yes
Therapy evaluation

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Algorithm for right heart failure

**Goal Values**
- ScvO2 > 70% or SvO2 > 65%
- MAP > 65 mmHg
- CI > 2.0 l/min
- CVP 8-12 mmHg, (depending on ventilation)
- PAOP 10-15 mmHg
- Diuresis ≥ 0.5 ml/kgBW/h
- Lactate < 3 mmol/l

**Therapy evaluation**

- Yes
  - Optimisation of therapies possible?
    - No
      - Surgical intervention?
        - No
          - Consider IABP / Assist Device
        - Yes
          - Therapy evaluation
  - Yes

**Procedure**

- Advanced haemodynamic monitoring with haemodynamic instability, decreasing CI and signs of peripheral congestion
- Increase in inotropy plus afterload reduction with vasodilators
  - Dobutamine ± PDE-inhibitor ± NTG
  - In PHT: inhalative NO, systemic and inhaled prostanoids
- In PHT: afterload reduction with vasodilators
- Hypotensive circulation MAP < 70 mmHg
  - Increase in inotropy with catecholamines and inodilators plus increase in peripheral resistance
  - If necessary afterload reduction
  - In PHT: inhalative vasodilators
- Normotensive circulation MAP > 70-80 mmHg
  - Increase in inotropy plus afterload reduction with vasodilators
  - Dobutamine ± PDE-inhibitor ± norepinephrine
  - If necessary epinephrine ± NTG
  - In PHT: inhalative NO, inhaled prostanoids
Scheme 7: Algorithm for IABP

Algorithm for IABP

IABP postoperatively

- Persistent or worsening LCOS despite treatment with high dose inotropes and vasoactive substances
- ST elevation and new evidence of hypokinesis (TEE) without the option of surgical or interventional correction
- Problematic anastomoses situation / inadequate revascularisation

Yes → Haemodynamic stabilisation

No → Consider assist device

Yes → Therapy evaluation