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Review

Meeting report of the First International Fluid Academy Day

Part 3: Results of the general and knowledge survey on fluid management and hemodynamic monitoring

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Abstract ***Background*** Fluid management in the critically ill has been neglected for way too long and although the use of less invasive hemodynamic monitoring is steadily increasing in the ICU, many questions remain unanswered. Recent data suggest that fluids should be dealt with as any other type of medication and that perioperative optimisation and goal directed therapy guided by hemodynamic monitoring could improve outcome. ***Objective*** To assess the awareness and current knowledge on fluid management and hemodynamic monitoring among critical care physicians. ***Methods*** A 14-item knowledge questionnaire was shown electronically to the participants of the 1st international fluid academy day (iFAD) held in Antwerp (Belgium) on November 19th in 2011. Each question was shown before the lecture covering the topic under study. The same questions were repeated at the end of the iFAD to see whether a learning curve could be observed. Results from the two voting sessions were compared. This paper reports on the global results of both parts of the questionnaire including 7 knowledge questions on fluid management and 7 knowledge questions on hemodynamic monitoring and fluid responsiveness. The respondents also provided information on their country of residence, basic speciality and years of experience and they gave feedback on general questions. Participants of the conference voluntarily completed the survey via a voting system and the answers were recorded automatically and exported to an Excel worksheet. Statistical analysis was performed with SPSS software. ***Results*** One hundred fifty nine (80%) of the 200 distributed voting pads among the 274 first iFAD participants were actively used during the conference day. The average overall score on the 14 knowledge questions on fluid management and hemodynamic monitoring after the first vote was 26±15.1% *vs* 45.9±20.7% after the second vote ($p<0.0001$). The best score after the first vote was for The Netherlands with 27.5±16.1% and Germany having the worst (19.4±14.7%). After the second vote this was again the Netherlands (49.1±21.9%) and again Germany (38±18.8%)(ANOVA p=NS). Residents in training had the best score with 33.8±20.3% after the first vote and they also had the best score after the second vote with 51.1±23% in ex-aequo with those with 1 to 5 years of experience 49.2±26.6% (ANOVA p=NS). Intensivists had the best score after the first vote with 31.2±14.9% and also performed best after the second vote 55.2±18.6% (ANOVA p=0.015). ***Conclusions*** With a global score of 26±15.1% after the first vote *vs* 45.9±20.7% after the second vote this survey confirms that there is a general lack of knowledge on fluid management, hemodynamic monitoring and assessment of preload and fluid responsiveness. Since correct fluid management and early intervention with goal directed therapy but also late conservative fluid management can reduce morbidity and mortality in critically ill patients, further educational efforts should be directed towards improving the knowledge on hemodynamic monitoring to guide this fluid management. This can be done by organising state of the art lectures and evaluating acquired knowledge with a voting system.

Key words albumin • cardiac output • colloids • crystalloids • fluid management • fluid responsiveness • knowledge • monitoring • survey • teaching • voting

Introduction

The first International Fluid Academy Day (IFAD, www.fluid-academy.org) was held on Saturday November 19th in 2011 at the "Elzenveld" Congress and Convention Centre in Antwerp, Belgium. This meeting was attended by 249 doctors, 25 faculty, 105 nurses together with 30 people form the industry totalling 350 medical workers. Fluid management in the critically ill has been neglected for way too long.

Many questions with regard to the type of fluids, the timing and the dosing remain unanswered. Recent data suggest that fluids should be dealt with as any other type of medication with indications and contraindications and possible side effects. Although the use of less invasive hemodynamic monitoring with either calibrated or uncalibrated techniques is steadily increasing in the intensive care unit (ICU), many questions with regard to the different techniques, their indications and pitfalls remain unanswered. Recent data suggest that perioperative optimisation and goal directed therapy guided by hemodynamic monitoring could improve outcome. The aim of this study was to assess the awareness and current knowledge on fluid management and hemodynamic monitoring among critical care physicians.

Methods

During the main medical symposium a voting system was used (n=200). A 14-item knowledge questionnaire was shown electronically to the participants of the 1st international fluid academy day (iFAD) held in Antwerp (Belgium) on November 19th in 2011. Each question was shown before the lecture covering the topic under study. The same questions were repeated at the end of the iFAD to see whether a learning curve could be observed. Results from the two voting sessions were compared. This paper reports on the global results of both parts of the questionnaire including 7 knowledge questions (KQ) on fluid management and 7 knowledge questions on hemodynamic monitoring and fluid responsiveness. The respondents also provided information on their country of residence, basic speciality and years of experience and they gave feedback on general questions (QS). Participants of the conference voluntarily completed the survey via a voting system and the answers were recorded automatically and exported to an Excel worksheet. Statistical analysis was performed with SPSS software.

Results

Demographics of respondents

The primary discipline of the respondents was anaesthesiology 36.5%, intensive care medicine 23.3%, emergency medicine 18.2%, internal medicine 18.2%, surgery 1.3% while 2.5% were not a doctor. The respondents resided in the following countries: Belgium 43.4%, The Netherlands 20.1%, United Kingdom 9.4%, Germany 5%, France 3.1%, and 18.9% came from other countries. With regard to the years of experience in the ICU, 6.3% answered to be in training, 11.9% had 1 to 5 years of experience, 18.9% between 5 and 15 and 44% stated to have more than 15 years experience, finally 18.9% answered not working in an ICU.

Hyperchloremic metabolic acidosis

GQ1. Do you believe hyperchloremic metabolic acidosis is a clinically relevant problem? Possible answers were:
1.Yes,
2. Probably,
3. Probably not and
4. No.

Figure 1 shows the distribution of answers (in percentage) on GQ1. In total 65% answered "yes", followed by 25% stating "no".

Crystalloids versus colloids

GQ2. Do you use colloids in the fluid management of septic shock (without signs of dehydration or anemia)? Possible answers were:
1. Yes, just colloids,
2. Yes, maintenance fluid (+/- 2L/24h) is crystalloids, rest is colloids,
3. Yes, colloids with a maximum of 50cc/kg/bw, rest is crystalloids,
4. Yes, fixed ratio of crystalloids/colloids, and 5) No, just crystalloids

Figure 2 shows the distribution of answers (in percentage) on GQ2. The majority (42%) answered "Yes, maintenance fluid (+/- 2L/24h) is crystalloids, rest is colloids".

Type of colloids

GQ3. What type(s) of colloid do you use? Possible answers were:
1. Gelatins,
2. Tetrastarch in an unbalanced solution,
3. Tetrastarch in a balanced solution,
4. Older starches,
5. Different types depending on the indication, and
6. I never use colloids

Figure 3 shows the distribution of answers (in percentage) on GQ3. The majority (38%) of participants use balanced starches.

Hypertonic solutions

GQ4. Do you use hypertonic solutions as an (additional) treatment for massive hemorrhage when there is no sign of brain edema? Possible answers were:
1. Always,
2. Regularly,
3. Rarely, and
4. Never

Figure 4 shows the distribution of answers (in percentage) on GQ4. The majority (64%) of participants never use hypertonic solutions.

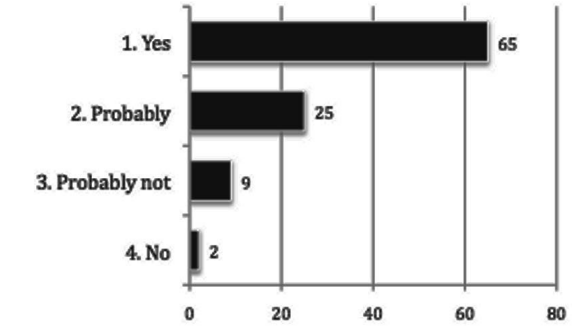

Fig. 1. Distribution of answers (in percentage) on general question 1 (GQ1): Do you believe hyperchloremic metabolic acidosis is a clinically relevant problem?

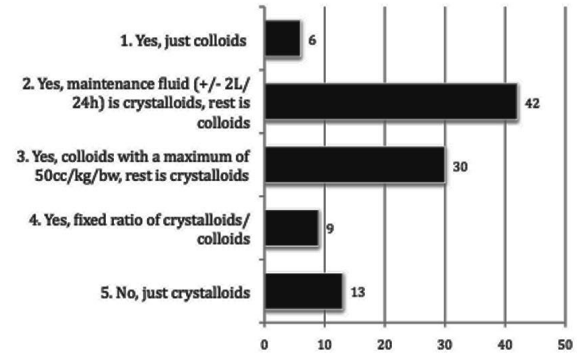

Fig. 2. Distribution of answers (in percentage) on general question 2 (GQ2): Do you use colloids in the fluid management of septic shock (without signs of dehydration or anemia)?

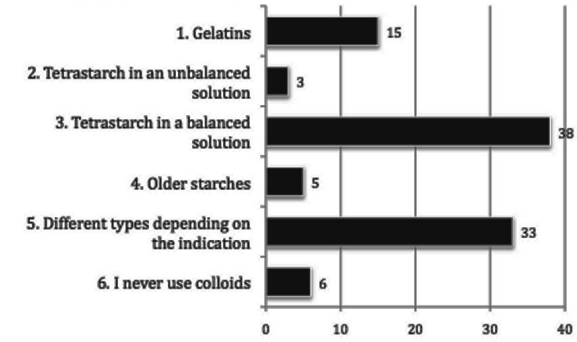

Fig. 3. Distribution of answers (in percentage) on general question 3 (GQ3): What type(s) of colloid do you use?

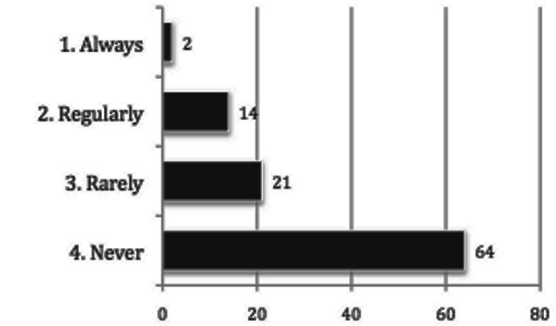

Fig. 4. Distribution of answers (in percentage) on general question 4 (GQ4): Do you use hypertonic solutions as an (additional) treatment for massive haemorrhage when there is no sign of brain edema?

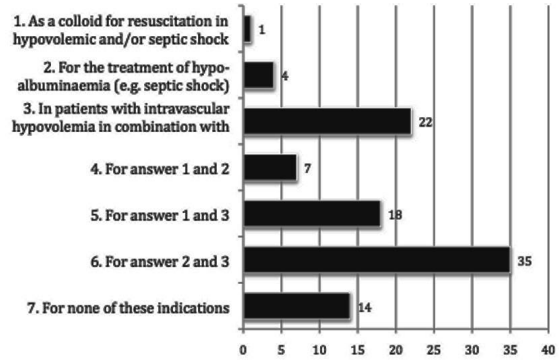

Fig. 5. Distribution of answers (in percentage) on general question 5 (GQ5): For which of these indications do you use hyperoncotic human albumin (e.g. 20%)?

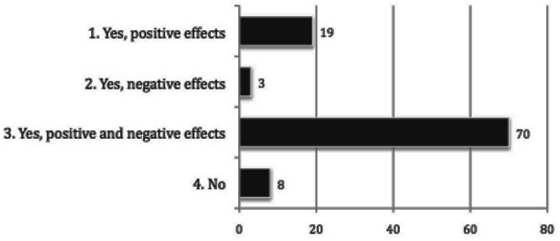

Fig. 6. Distribution of answers (in percentage) on general question 6 (GQ6): Do you think the last generation starches have capacities beyond resuscitation?

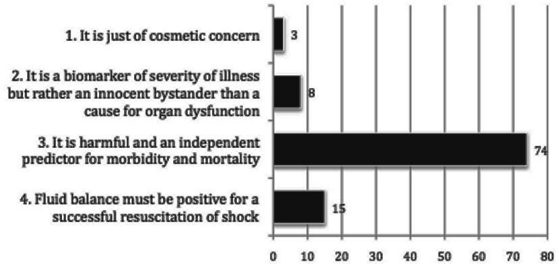

Fig. 7. Distribution of answers (in percentage) on general question 7 (GQ7): What is your opinion about a positive cumulative fluid balance in septic shock?

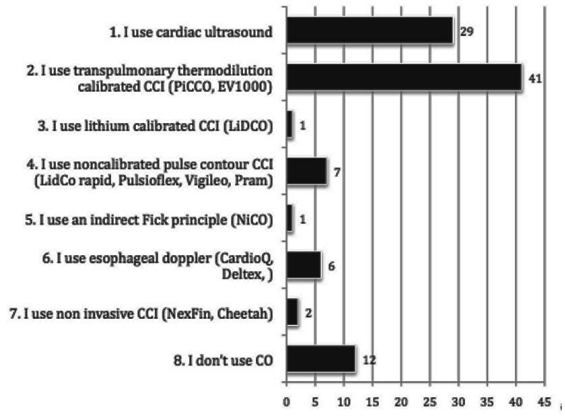

Fig. 8. Distribution of answers (in percentage) on general question 8 (GQ8): How do you monitor cardiac output most often? CCI: continuous cardiac index, CO: cardiac output

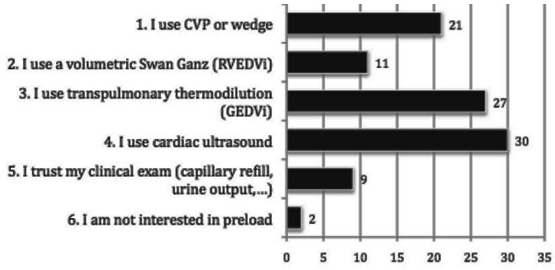

Fig. 9. Distribution of answers (in percentage) on general question 9 (GQ9): What is your preferred preload parameter? CVP: central venous pressure, GEDVI: global enddiastolic volume index, RVEDVI: right ventricular enddiastolic volume index

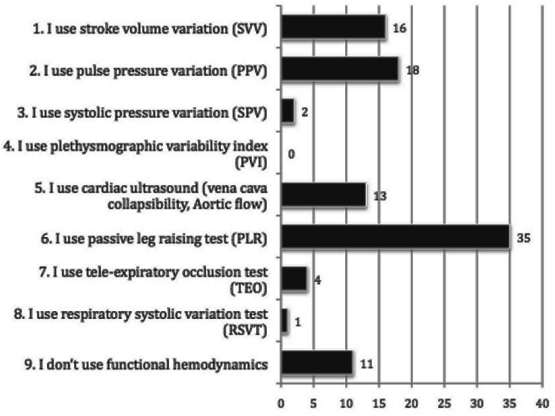

Fig. 10. Distribution of answers (in percentage) on general question 10 (GQ10): What is your preferred index or test for fluid responsiveness?

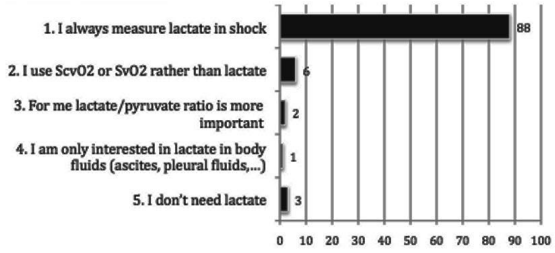

Fig. 11. Distribution of answers (in percentage) on general question 11 (GQ11): How do you use lactate?

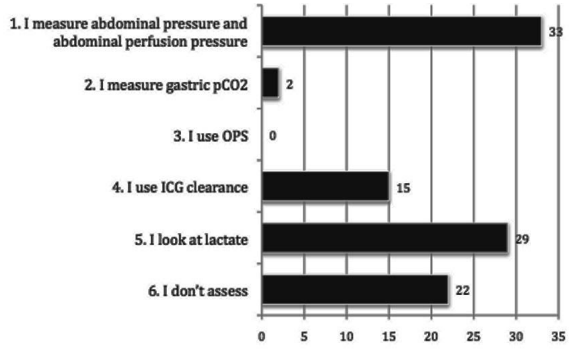

Fig.12. Distribution of answers (in percentage) on general question 12 (GQ12): How do you most often assess hepatosplanchnic perfusion? OPS: orthogonal polarization spectroscopy

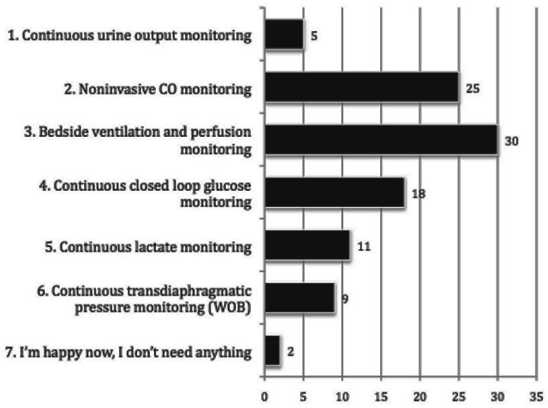

Fig. 13. Distribution of answers (in percentage) on general question 13 (GQ13): What would be the most valuable new technology development in your ICU?

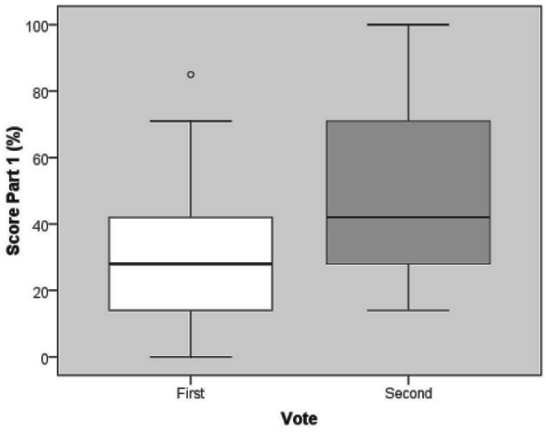

Fig. 14. Boxplots showing final total score on knowledge questions 1 to 14 (KQ1 – KQ14) expressed as a percentage before the lecture (white box, first vote) and after the lecture had been given (grey box, second vote)(p<0.0001)

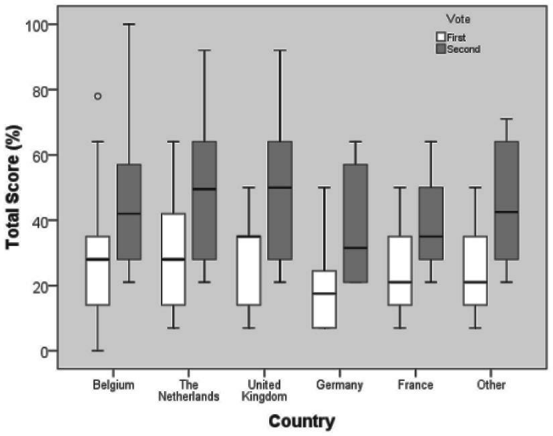

Fig. 15. Boxplots showing final total score on knowledge questions 1 to 14 (KQ1 – KQ14) expressed as a percentage before the lecture (white box, first vote) and after the lecture had been given (grey box, second vote) and according to country of origin of participant. P-value <0.0001 for all comparisons between vote 1 and vote 2 except p=0.004 for United Kingdom, p=0.044 for Germany and p=NS for France.

Albumin

GQ5. For which of these indications do you use hyperoncotic human albumin (e.g. 20%)? Possible answers were:
1. As a colloid for resuscitation in hypovolemic and/or septic shock,
2. For the treatment of hypo-albuminaemia (e.g. septic shock),
3. In patients with intravascular hypovolemia in combination with clinically relevant interstitial edema (lung edema, burns, abdominal hypertension,…),
4. For answer 1 and 2,
5. For answer 1 and 3,
6. For answer 2 and 3, and
7. For none of these indications.

Figure 5 shows the distribution of answers (in percentage) on GQ5. The majority (35%) of participants use albumin for treatment of hypo-albuminemia in septic shock or in patients with hypovolemia in combination with capillary leak, while 22% only use it in the latter.

Starches

GQ6. Do you think the last generation starches have capacities beyond resuscitation? Possible answers were:
1. Yes, positive effects,
2. Yes, negative effects,
3. Yes, positive and negative effects,
4. No

Figure 6 shows the distribution of answers (in percentage) on GQ6. The majority (70%) of participants believe that the newer starches have both positive and negative effects.

Fluid balance

GQ7. What is your opinion about a positive cumulative fluid balance in septic shock? Possible answers were:
1. It is just of cosmetic concern,
2. It is a biomarker of severity of illness but rather an innocent bystander than a cause for organ dysfunction,
3. It is harmful and an independent predictor for morbidity and mortality and
4. Fluid balance must be positive for a successful resuscitation of shock

Figure 7 shows the distribution of answers (in percentage) on GQ7. The majority (74%) of participants is convinced that a positive cumulative fluid balance is harmful.

Hemodynamic monitoring

GQ8. How do you monitor cardiac output most often? Possible answers were:
1. I use cardiac ultrasound,
2. I use transpulmonary thermodilation calibrated CCI (PiCCO, EV1000),
3. I use lithium calibrated CCI (LiDCO),
4. I use noncalibrated pulse contour CCI (LidCo rapid, Pulsioflex, Vigileo, Pram),
5. I use an indirect Fick principle (NiCO),
6. I use esophageal doppler (CardioQ, Deltex),
7. I use non invasive CCI (NexFin, Cheetah), and
8. I don't use CO.

Figure 8 shows the distribution of answers (in percentage) on GQ8. The majority of participants uses transpulmonary thermodilution (41%), followed by cardiac ultrasound (29%), however it is frightening that 11% do not measure CO.

Preload

GQ9. What is your preferred preload parameter? Possible answers:
1. I use CVP or wedge,
2. I use a volumetric Swan Ganz (RVEDVi),
3. I use transpulmonary thermodilution (GEDVi),
4. I use cardiac ultrasound,
5. I trust my clinical exam (capillary refill, urine output,…), and
6. I am not interested in preload

Figure 9 shows the distribution of answers (in percentage) on GQ9. The majority (30%) of participants uses cardiac ultrasound and transpulmonary thermodilution (27%), however 21% still use the CVP!

Fluid responsiveness

GQ10. What is your preferred index or test for fluid responsiveness? Possible answers were:
1. I use stroke volume variation (SVV),
2. I use pulse pressure variation (PPV),
3. I use systolic pressure variation (SPV),
4. I use plethysmographic variability index (PVI),
5. I use cardiac ultrasound (vena cava collapsibility, Aortic flow),
6. I use passive leg raising test (PLR),
7. I use tele-expiratory occlusion test (TEO),
8. I use respiratory systolic variation test (RSVT), and
9. I don't use functional hemodynamics.

Figure 10 shows the distribution of answers (in percentage) on GQ10. The majority (35%) of participants uses the passive leg raising test, followed by PPV (18%) and SVV (16%), however 11% do not use functional hemodynamics at all!

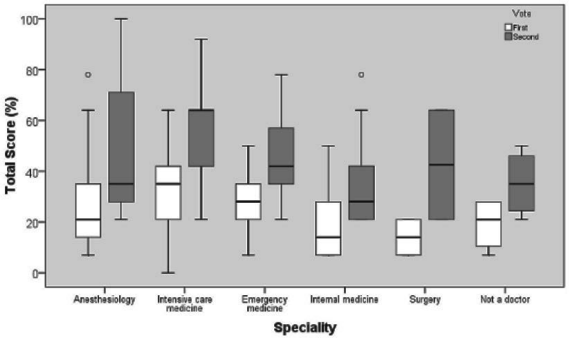

Fig. 16. Boxplots showing final total score on knowledge questions 1 to 14 (KQ1 – KQ14) expressed as a percentage before the lecture (white box, first vote) and after the lecture had been given (grey box, second vote) and according to primary speciality of participant. P-value <0.0001 for all comparisons between vote 1 and vote 2, except for surgery and those not being doctors (p=NS).

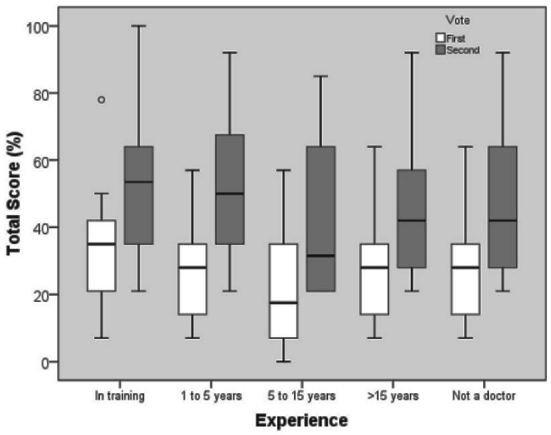

Fig. 17. Boxplots showing final total score on knowledge questions 1 to 14 (KQ1 – KQ14) expressed as a percentage before the lecture (white box, first vote) and after the lecture had been given (grey box, second vote) and according to years of training of the participant. P-value <0.0001 for all comparisons between vote 1 and vote 2, except for those in training (p=0.09).

Lactate

GQ11. How do you use lactate? Possible answers were:
1. I always measure lactate in shock,
2. I use $ScvO_2$ or SvO_2 rather than lactate,
3. For me lactate/pyruvate ratio is more important,
4. I am only interested in lactate in body fluids (ascites, pleural fluids,…), and
5. I don't need lactate

Figure 11 shows the distribution of answers (in percentage) on GQ11. The majority (74%) of participants are convinced that a positive cumulative fluid balance is harmful.

Hepatosplanchnic perfusion

GQ12. How do you most often assess hepatosplanchnic perfusion? Possible answers were:
1. I measure abdominal pressure and abdominal perfusion pressure,
2. I measure gastric pCO2,
3. I use orthogonal polarization spectroscopy (OPS),
4. I use indocyanine green (ICG) clearance,
5. I look at lactate, and
6. I don't assess.

Figure 12 shows the distribution of answers (in percentage) on GQ12. The majority (33%) of participants use IAP, followed by lactate (29%), it is frightening however that 22% do not assess hepatosplanchnic perfusion.

Future techniques

GQ13. What would be the most valuable new technology development in your ICU? Possible answers were:
1. Continuous urine output monitoring,
2. Noninvasive CO monitoring,
3. Bedside ventilation and perfusion monitoring,
4. Continuous closed loop glucose monitoring,
5. Continuous lactate monitoring,
6. Continuous transdiaphragmatic pressure monitoring (WOB), and
7. I'm happy now, I don't need anything.

Figure 13 shows the distribution of answers (in percentage) on GQ13. The majority (30%) of participants want bedside monitoring of ventilation and perfusion, followed by noninvasive CO monitoring (25%), it is surprising that only 5% are interested in continuous urine output measurement.

Final knowledge score on hemodynamic monitoring

The final score obtained by adding the individual results for KQ1 to KQ14 is shown in Figure 14. A significant increase was observed in the total final score from 26±15.1% *vs* 45.9±20.7% after the second vote (p<0.0001). The best score after the first vote was for The Netherlands with 27.5±16.1% and Germany having the worst (19.4±14.7%). After the second vote this was again the Netherlands (49.1±21.9%) and again Germany (38±18.8%)(ANOVA p=NS). Residents in training had the best score with 33.8±20.3% after the first vote and they also had the best score after the second vote with 51.1±23% in ex-aequo with those with 1 to 5 years of experience 49.2±26.6% (ANOVA p=NS). Intensivists had the best score after the first vote with 31.2±14.9% and also performed best after the second vote 55.2±18.6% (ANOVA p=0.015).

Figure 15 shows the evolution of the final total score for each country (a significant increase was observed in all countries except France) and Figure 16 shows the final total score according to primary speciality (a significant increase was observed for all specialities except surgery and those not being a doctor).

Figure 17 shows the final total score according to the years of training (a significant increase was observed for all specialities except those being in training).

Discussion

Fluid management

The answers to the general questions reveal some interesting points for further discussion. It is re-assuring that the majority of participants is convinced that hyperchloremic metabolic acidosis is a clinically relevant topic, as this has been the subject of recent research (albeit retrospectively) [1]. However, as of today no large randomized controlled clinical trials are available comparing balanced *vs* unbalanced solutions.

Fluid management in septic shock is mainly based on administration of colloids (given next to a crystalloid maintenance fluid of 84ml/hr) in order to rapidly restore the intravascular space and avoid to large amounts of fluid given that may result a positive cumulative fluid balance. Recent data also show that colloids but not crystalloids prevent increase in the gut wet-to-dry ratio and gut edema [2, 3]. Increased gut edema on the other hand results in diminished intestinal contractility [4]. Decreased contractility may further promote ileus, intestinal swelling, increased intra-abdominal pressure, mesenteric vein compression and venous hypertension, triggering a vicious cycle leading to more fluid administration [5—8]. Although few data are available to support their general use, it is also good to know that the majority of iFAD participants are using balanced last generation starches as their preferred colloid [9, 10]. Hypertonic solutions and especially small volume resuscitation (at a dose of 4ml/kg given over 10 minutes) may have some indications and beneficial effects over normal crystalloid or colloid administration, however the majority of participants stated never to use hypertonic solutions [11, 12]. Recent data and results from meta-analyses confirm the potential beneficial effects of albumin (and especially hyperoncotic albumin 20%), in patients with septic shock and capillary leak, the majority of participants uses albumin to correct hypo-albuminemia in this setting [13—16]. However one must avoid to use albumin in the setting of traumatic brain injury or intracranial hypertension [17]. The last word has not been said with regard to the eternal colloid *vs* crystalloid debate, however in view of the results of the recent large multicentre trials one must be very cautious when it comes to fluid administration, and the best fluid is probably the one that has not been given [18—20]. A mixed fluid regimen approach combining crystalloid maintenance fluid with a mixture of new generation balanced waxy maze starches, hyperoncotic albumin and blood products seems the best option to guarantee that the oxygen gets to the tissues. Fluids must be seen and treated as any other drug we give to our patients with indications and contra-indications and possible side effects on renal and liver function and coagulation parameters. Avoiding fluid overload and avoiding a positive cumulative fluid balance with the instauration of late conservative fluid management or even late goal directed fluid removal may even have a greater impact on outcome than the initial early goal directed therapy [21].

Hemodynamic monitoring, preload and fluid responsiveness

In order to guide our fluid management we must perform hemodynamic monitoring and while the pulmonary artery catheter may have become obsolete after the negative trials [22—24] it is always better to perform some kind of monitoring because clinical examination with estimation of CO is far from accurate. Noninavsive CO monitoring devices have gained their place in the modern ICU and the calibrated transpulmonary thermodilution techniques (with PiCCO or EV1000) seem most popular in difficult unstable critical care patients with changing conditions of preload, afterload and contractility. Defining the optimal preload is the first step in hemodynamic management and optimization. Although the majority of iFAD participants use either cardiac ultrasound or volumetric preload indicators it is frightening that still 21% use the CVP as preload indicator [25]. Chasing a static CVP target value may however lead to underresusciation or unnecessary overresuscitation [26—32]. Assessment of fluid responsiveness may even be more important than defining cardiac preload since regardless of a low, normal or high preload the patient may still be fluid responsiveness. It is re-assuring that only 11% from the participants stated that they never use functional hemodynamic parameters, although the ultimate goal should be that every-one uses these parameters before fluid administration. The use of SVV or PPV in combination with the passive leg raising test or the end-expiratory occlusion test may prevent unnecessary fluid boluses from being administered to the patient [31]. The European definition of shock states that a patient is in shock when there is a mismatch between oxygen delivery and oxygen consumption, as evidenced by increased lactate levels. The majority of participants use lactate levels in shock patients [33—35]. Gastro-intestinal dysfunction is hard to measure and quantify and this was the subject of a recent consensus report [36]. The mechanism of gastro-intestinal injury (related to increased vascular permeability) is widely recognized and accepted in the lung and kidneys, where it is classified as acute lung and kidney injury (ALI/AKI) [37]. The same pathological process occurs in the gut, but this concept is much slower to seep through. However, the role of the gut as the motor of organ dysfunction syndrome cannot be denied and difficulties in assessing gut function should not deter us from recognizing that concept [38]. New techniques like the measurement of abdominal perfusion pressure (defined as mean arterial pressure minus IAP), indocyanine green plasma

disappearance rate other dye dilution techniques, or serum levels of citrulline and i-FABP may help us to better understand the impact of sepsis on the GI tract.

Other future techniques like continuous urine output, noninvasive CO, closed loop glucose, lactate, bedside ventilation and perfusion monitoring may help us to better guide our fluid management.

Not only accuracy and precision but also continuity of measurement (and keeping track of changes) offers vital insights that may be hidden in the analog signals of our future monitors. "Physiological Examination" - observing multiple parameters on the monitor in real time – should be considered to be (at least) as important as the classic "Physical Examination".

Conclusions

With an average total score of 26±15.1% after the first vote *vs* 45.9±20.7% after the second vote, this survey demonstrates that there is a general lack of knowledge on hemodynamic monitoring and assessment of preload and fluid responsiveness. Since correct fluid management and early intervention with goal directed therapy but also late conservative fluid management can reduce morbidity and mortality in critically ill patients, further educational efforts should be directed towards improving the knowledge on hemodynamic monitoring to guide this fluid management. This can be done by organising state of the art lectures and evaluating acquired knowledge with a voting system to detect a positive learning curve. The future of fluid management and hemodynamic monitoring depends not only on new fluids and new technologies but also on our recognition of the complexities of hemodynamic monitoring in relation to guiding our fluid management.

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