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Cerebral arterial gas embolism in a diver using closed-circuit rebreather diving apparatus

Si Jack Chong and Teck Wei Tan

Key words

Cerebral arterial gas embolism (CAGE), closed-circuit underwater breathing system, recompression therapy

Abstract

(Chong SJ, Tan TW. Cerebral arterial gas embolism in a diver using closed-circuit rebreather diving apparatus. *Diving and Hyperbaric Medicine*. 2008; 38: 46-7.)

A Singaporean naval diver suffered symptoms and signs of cerebral arterial gas embolism (CAGE) following a panicked ascent from a depth of 5–6 metres' sea water while using a Dräger LAR V closed-circuit oxygen rebreather system. He presented with altered mental status and paresis. CAGE due to gas mixtures with high oxygen content has seldom been reported. The diver had no sequelae following prompt recompression therapy. This positive clinical outcome may be attributable to the high oxygen content in the diver's inspired gas and/or the promptness of recompression.

Introduction

Pulmonary barotrauma following ascent from depth whilst diving is one of the most serious forms of all barotraumas. Gas in the lungs expands during ascent and may rupture into adjacent lung tissues, resulting in mediastinal emphysema, pneumothorax or arterial gas embolism.¹ Cerebral arterial gas embolism (CAGE) is of particular concern as the vascular damage, hypoxia and the triggering of the inflammatory cascade in cerebral vessels may result in high rates of relapse, neurological deficits and even death.² CAGE has been widely reported with the use of open-circuit compressed gases, but there have been few reports of pulmonary barotrauma associated with closed-circuit rebreather (CCR) diving systems.^{3,4} This may be due to several factors, including the experience of the divers using the CCRs and the high oxygen (O₂) content in the gases used in these diving systems.

We present the case of a young, healthy Royal Singapore Navy (RSN) diver who presented with symptoms and signs of CAGE after an uncontrolled ascent while using a CCR

system. He responded clinically to recompression therapy and did not demonstrate any sequelae at follow up.

Case report

A 21-year-old RSN diver with nearly two years' diving experience was performing a routine compass dive for 60 minutes just outside the naval camp, with a maximum depth of 5–6 metres' sea water (msw) and using the Dräger LAR V oxygen CCR system. The O₂ concentration of the breathing gas in the LAR V CCR has been shown to be up to 74%.⁵ The diver had completed about 35 minutes of his training dive when he developed difficulties with his mouthpiece and subsequently panicked and ascended uncontrollably to the surface as he seemed to be "choking".

At the surface, the dive supervisor noted that the diver had altered sensorium as he could not recognise his supervisor. He was thrashing about wildly but was relatively weak. The dive supervisor rapidly rescued him and administered 100% oxygen while evacuating him to the recompression facility within the nearby naval camp.

At the recompression facility, intravenous hydration was commenced. Blood pressure and heart rate were normal but there was tachypnoea of 22 breaths/min and pulse oximetry showed a decrease in oxygen saturation (92%) on 40% oxygen. There was altered mental status with a GCS score of 11 (E3 M4 V4) and the patient was not orientated to time, place or person. Neurological examination revealed generalised weakness with Medical Research Council grade of 4/5. An urgent chest X-ray did not demonstrate emphysema or pneumothorax.

A diagnosis of CAGE was made and recompression therapy was initiated within 35 minutes of the accident using the USN Treatment Table 6 (USN T6). The patient's symptoms began to improve at depth and achieved complete resolution by the first air break. A neurological examination done at depth demonstrated complete mental acuity and full power. The entire treatment table was completed and the patient monitored overnight with no relapse or sequelae. The patient underwent a repeat USN T6 the following day.

The blood investigations done showed a normal full blood count and urea, glucose and electrolyte levels within normal limits. A computed tomography (CT) scan of the patient's chest and a spirometry performed three months later did not reveal any abnormality. He returned to active diving six months after the incident.

Discussion

The expert opinion is that serious symptoms that develop immediately after ascent must be regarded as AGE and treated accordingly until a definitive diagnosis can be made.¹ Experimentally, cadaveric lungs have been shown to burst at pressures as low as 70 mmHg. In addition, there have been reports of intensive-care patients with lung ruptures following positive pressure of more than 70 mmHg.¹ This is approximately equivalent to an ascent of one metre in water. There have also been reports of CAGE occurring following ascents of one metre depth of water.⁶

The diver in this case suffered a CAGE following a rapid uncontrolled ascent from a depth of about 6 msw while using the LAR V CCR system. The rapid manifestation of his clinical symptoms on surfacing and signs of altered mental status with paresis were classical for CAGE. However, early recompression following CAGE carries a good prognosis, as seen in our patient.

The interesting aspect of this case was that the diver suffered a CAGE while using a Dräger LAR V oxygen CCR system. Using the single fill/empty cycle purge procedure developed by Thalmann and Butler, a diver can effectively increase the oxygen concentration in his breathing gas to 74%, in contrast to the 20.9% found in normal air.⁵ This was the most likely oxygen concentration in the breathing gas of our patient at the time of the incident. With this oxygen-rich gas mixture, the gas bubbles responsible for the pathogenesis of this case of CAGE should theoretically be more easily metabolised

by the surrounding tissues, reducing in size rapidly, and the oxygen content should mitigate the hypoxic effects of air embolism to tissues. The rapid and complete resolution of the symptoms may thus be contributed to by the high oxygen content. In a similar report by Carstairs the patient also achieved complete resolution.⁴ The rapid initiation of treatment (within 35 minutes of the incident), thanks to the proximity of the recompression facility to the dive site, also would have contributed to the positive outcome.

Mediastinal emphysema, pneumothorax and local pulmonary damage may be associated with CAGE. However the subsequent CT scan of this patient's thorax did not reveal any pulmonary changes or pathologies. There were also no changes in the spirometry results of this patient. These follow-up medical investigations help to ascertain the future risk factors for diving, as well as shed light on the origins of pulmonary barotrauma. Even if there has been a history of rapid ascent, the presence of pulmonary bullae or other abnormalities must be sought.

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Editor's comment:

Overdistension and overpressurisation of the lung are thought to be the underlying causes of pulmonary barotrauma and arterial gas embolism (AGE), but the exact mechanisms of injury remain unclear. Much of the clinical work on AGE relates to the submarine escape training environment, which may differ in several important ways from scuba diving injuries. Most importantly the diver has a greater degree of gas loading and recompression is often delayed, sometimes for many hours, resulting in much poorer outcomes than in the immediate recompression of escape trainees¹ or of the military diver described by Chong and Tan. A subgroup of AGE victims demonstrates a relapsing or secondary deterioration course, either as a result of the neutrophil-mediated secondary injury that occurs or from the onset of decompression sickness, the so-called Type III decompression sickness, as may possibly have been the situation in the second of Wilson and Sayer's cases.

Symptoms and signs typically develop within five minutes of the incident – frequently an uncontrolled or rapid ascent due to running out of air or buoyancy problems. There is an apparent inverse relationship between severity and the time

to onset. Neuman reports an 18% incidence of convulsions in 74 diving accidents with cerebral arterial gas embolism (CAGE).² However, this rate appears much higher than that in the Scottish series, and in our own experience in South Island, New Zealand (Davis FM, unpublished observations). In 83 decompression illness cases treated in the Christchurch unit over eight years, 17 (1 in 5) divers had a definitive diagnosis of CAGE and four others had possibly suffered a CAGE. Of these, only one had a documented seizure either at the site of the accident or subsequently. Seizure associated with CAGE tends to carry a very poor prognosis according to anecdotal reports from other hyperbaric units and may commonly be associated with cardio-respiratory arrest and death.

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Position available

Hyperbaric Medicine + Anaesthesia or Emergency Medicine Specialist

Vacancies #: 6308 + 6946 (Anaesthesia; no # for EM)

Closing date: 09 May 2008 (Late applications will be accepted)

The Hyperbaric Medicine Unit (HMU), Christchurch Hospital has a 0.4 FTE position to replace a retiring member of the senior staff. This vacancy will be combined with either Anaesthesia or Emergency Medicine sessions to create a full-time specialist position.

CDHB is a busy tertiary referral centre in South Island of New Zealand, with close links to the University of Otago Christchurch School of Medicine and Health Sciences situated on the Christchurch Hospital site. Surgical services include all the main surgical specialties, whilst the Department of Medicine covers all major sub-specialties. There is a regional Spinal Injuries Unit and a Bone Marrow Transplant Unit, and the Emergency Department is the busiest in New Zealand.

HMU is administered within the Anaesthetic Department and is currently being assessed by the ANZ College of Anaesthetists for approval for resident training in hyperbaric medicine. The HMU provides a full range of hyperbaric services for the Canterbury District Health Board (CDHB), and is a referral centre for other DHBs in South Island and some parts of North Island. Clinical practice is based on the UHMS and ANZHMG guidelines. We operate a 4 ATA-capable rectangular multiplace chamber providing

around 1,300 treatments per year. Our patients range from ambulatory through critically ill, and we provide a 24/7 emergency service [visit <www.cdhb.govt.nz/hbu/>].

Applicants should have appropriate training and experience in hyperbaric medicine, and an Emergency Medicine or Anaesthesia post-graduate qualification recognised for vocational registration by the Medical Council of New Zealand. Foreign graduates will need to meet all immigration and medical council requirements. A successful appointee in Anaesthesia would preferably have generalist skills with a focus on day surgery, acute theatre work, preassessment, and elective orthopaedics. Flexibility in covering other lists is also required and the ability to work in obstetrics would be an advantage.

Christchurch ("The Garden City") is a university city (Canterbury, Lincoln and Otago Universities) of about 365,000 people. It is situated on the East Coast of South Island close to the Banks Peninsula and the commercial harbour town of Lyttelton, and is an hour's drive from the Southern Alps. A wide range of outdoor recreational activities are readily accessible locally and throughout South Island [visit <www.ccc.govt.nz/>].

For the position description contact:

Human Resources, Christchurch Hospital

Phone: +64-(0)3-364-0198 or +64-(0)3-364-0133

E-mail: <hradmin@cdhb.govt.nz>

SPUMS notices and news

South Pacific Underwater Medicine Society Diploma of Diving and Hyperbaric Medicine

Requirements for candidates

In order for the Diploma of Diving and Hyperbaric Medicine to be awarded by the Society, the candidate must comply with the following conditions:

- 1 The candidate must be medically qualified, and be a financial member of the Society of at least two years' standing.
- 2 The candidate must supply evidence of satisfactory completion of an examined two-week full-time course in Diving and Hyperbaric Medicine at an approved Hyperbaric Medicine Unit.
- 3 The candidate must have completed the equivalent (as determined by the Education Officer) of at least six months' full-time clinical training in an approved Hyperbaric Medicine Unit.
- 4 The candidate must submit a written proposal for research in a relevant area of underwater or hyperbaric medicine, and in a standard format, for approval by the Academic Board before commencing their research project.
- 5 The candidate must produce, to the satisfaction of the Academic Board, a written report on the approved research project, in the form of a scientific paper suitable for publication.

Additional information

The candidate must contact the Education Officer to advise of their intended candidacy, seek approval of their courses in Diving and Hyperbaric Medicine and training time in the intended Hyperbaric Medicine Unit, discuss the proposed subject matter of their research, and obtain instructions before submitting any written material or commencing a research project.

All research reports must clearly test a hypothesis. Original basic or clinical research is acceptable. Case series reports may be acceptable if thoroughly documented, subject to quantitative analysis, and the subject is extensively researched and discussed in detail. Reports of a single case are insufficient. Review articles may be acceptable if the world literature is thoroughly analysed and discussed, and the subject has not recently been similarly reviewed. Previously published material will not be considered.

It is expected that all research will be conducted in accordance with the joint NHMRC/AVCC statement and guidelines on research practice (available at <http://www.health.gov.au/nhmrc/research/general/nhmrcavc.htm>) or the

equivalent requirement of the country in which the research is conducted. All research involving humans or animals must be accompanied by documented evidence of approval by an appropriate research ethics committee. It is expected that the research project and the written report will be primarily the work of the candidate.

The Academic Board reserves the right to modify any of these requirements from time to time. The Academic Board consists of:

Dr Fiona Sharp, Education Officer, Professor Des Gorman and Dr Chris Acott.

All enquiries should be addressed to the Education Officer:

*Dr Fiona Sharp,
249c Nicholson Road
Shenton Park, WA 6008
Australia*

E-mail: <sharpief@doctors.org.uk>

Key words

Qualifications, underwater medicine, hyperbaric oxygen, research

SPUMS website news

Hello to all from your friendly SPUMS Webmaster. There have been a couple of things happening with the website over recent times. Firstly (and most importantly) we have started uploading full copies of the SPUMS Journal to the Rubicon Foundation Website. These will be updated to all the journals except for the last three years, which will eventually become a members only access portal on our website. This is a significant advance for SPUMS as it raises our profile in the hyperbaric world and I feel a few of our northern hemisphere colleagues will be more than a little surprised at the quality and breadth of research from the southern half of the planet. Currently we have Volumes 1–30 being uploaded at the Rubicon Foundation, which can be accessed by going to the Links page on the SPUMS website. Rubicon has also indexed the journal to make it searchable online. Thanks to Gene Hobbs from The Rubicon Foundation for doing this and also to all the members who have supported this initiative.

I have added another link area to our site called "Other notices", which currently has one section of SPUMS-approved notices namely job opportunities in hyperbaric medicine. SPUMS has had a general policy of minimal advertising in its journal but it was thought that advertising job opportunities could help members increase their participation in the organisation so this area is more of a

community notice area. Anyone who wants to utilise this facility should submit a request to the SPUMS Committee via the Secretary and we will deal with it on a case-by-case basis.

Finally, I have added a link to the Historical Diving Society–Asia Pacific as there has been a warm relationship between SPUMS and HDS-AP involving complimentary journal swapping and genuine cross-topic interest. If you have any interest in diving history, I recommend visiting the HDS–AP site (see link on <www.spums.org.au>) as they have some great stories that would make most hyperbaric physicians have nightmares!

Regards to all,

Glen Hawkins, SPUMS Webmaster

SPUMS Annual General Meeting 2008

The AGM for SPUMS 2008 is to be held at Liamo Resort, Kimbe WNB, PNG, at 1000 hr, Wednesday 28 May 2008.

Agenda

Apologies:

Minutes of the previous meeting:

Minutes of the previous meeting will be posted on the notice board at Liamo Resort and were published in *Diving and Hyperbaric Medicine*. 2007; 37(2): 101-4.

Matters arising from the minutes:

Annual reports:

President's report
Secretary's report
Education Officer's report
Annual financial statement and Treasurer's report

Subscription fees for 2009:

Proposed by the Treasurer, seconded by the Secretary:
Full members AUD\$150.00 (internet transaction);
AUD\$170 (manual/paper-based transaction)
Associate /other members AUD\$80 (internet transaction);
AUD\$100 (manual/paper-based transaction)

Election of office bearers:

President
Secretary
Education Officer
Committee Members (2)

Appointment of the Auditor 2008:

Proposed by the Treasurer, seconded by the Secretary:
Barrett, Baxter and Bye, 60 Albert Road, South Melbourne 3205

Business of which notice has been given:

Motion to elect Neal Pollock, PhD, to full Membership of the Society.
Proposer: Mike Davis; seconder: Simon Mitchell

ANZCA Certificate in Diving and Hyperbaric Medicine

Eligible candidates are invited to present for the examination for the Certificate in Diving and Hyperbaric Medicine of the Australian and New Zealand College of Anaesthetists.

Eligibility criteria are:

- 1 Fellowship of a Specialist College in Australia or New Zealand. This includes all specialties, and the Royal Australian College of General Practitioners.
 - 2 Completion of training courses in Diving Medicine and in Hyperbaric Medicine of at least 4 weeks' total duration. For example, one of:
 - a ANZHMG course at Prince of Wales Hospital Sydney, **and** Royal Adelaide Hospital or HMAS Penguin diving medical officers course **OR**
 - b Auckland University Diploma in Diving and Hyperbaric Medicine.
 - 3 **EITHER:**
 - a Completion of the Diploma of the South Pacific Underwater Medicine Society, including 6 months' full-time equivalent experience in a hyperbaric unit and successful completion of a thesis or research project approved by the Assessor, SPUMS.
 - b **and** Completion of a further 12 months' full-time equivalent clinical experience in a hospital-based hyperbaric unit which is approved for training in Diving and Hyperbaric Medicine by the ANZCA.
- OR:**
- c Completion of 18 months' full-time equivalent experience in a hospital-based hyperbaric unit which is approved for training in Diving and Hyperbaric Medicine by the ANZCA
 - d **and** Completion of a formal project in accordance with ANZCA Professional Document TE11 "Formal Project Guidelines". The formal project must be constructed around a topic which is relevant to the practice of Diving and Hyperbaric Medicine, and must be approved by the ANZCA Assessor prior to commencement.
- 4 Completion of a workbook documenting the details of clinical exposure attained during the training period.
 - 5 Candidates who do not hold an Australian or New Zealand specialist qualification in Anaesthesia, Intensive Care or Emergency Medicine are required to demonstrate airway skills competency as specified by ANZCA in the document "Airway skills requirement for training in Diving and Hyperbaric Medicine".

All details are available on the ANZCA website at:
<www.anzca.edu.au/edutrain/DHM/index.htm>

*Dr Margaret Walker, FANZCA
Chair, ANZCA/ASA Special Interest Group in Diving and Hyperbaric Medicine*

SPUMS Annual Scientific Meeting 2008

Dates: May 24 – 31

Venue: Liamo Resort, Kimbe WNB, Papua New Guinea

Guest speakers:

Professor Alf Brubakk
Associate Professor Richard Moon
Dr David Williams

Themes:

The Treatment Tables
Tropical/Envenomation Medicine Update
Resuscitation Update

Alf Brubakk is from the Norwegian University of Science and Technology in Trondheim, Norway, and was one of the editors of the 5th edition of Bennett and Elliott's *Physiology and medicine of diving*. Richard Moon is Associate Professor of Anesthesiology at Duke University Medical Center, USA, and Medical Director of DAN International. David Williams is a research scientist attached to the Australian Venom Research Unit at the University of Melbourne, Australia. His primary interest is in the management of the envenomed victim in tropical countries.

For registration go to the SPUMS website: <www.spums.org.au>
click on 'Conference Registration'. Early registration/booking is recommended.

Abstracts for presentations are very welcome and should be submitted to the Convenor before 30 April 2008 as a Word file of up to 250 words (excluding references – 4 only) and with only one figure.

Conference attendees will be able to receive CME points from relevant medical bodies (RACGP, ANZCA, NZCGP, etc).

Convenor: Dr Chris Acott
E-mail: <cacott@optusnet.com.au>
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34th Scientific Meeting of the European Underwater & Baromedical Society

Graz, Austria, 3 to 6 September 2008



Welcome to Graz!

We are proud and happy to organize this year's EUBS conference for you. Come and join us in Graz, elected European cultural capital in 2003, capital of Styria, the "green heart of Austria"!

Univ. Prof. Dr Freyja Maria Smolle-Jüttner

Dr Beatrice Ratzenhofer-Komenda

Dr Winfried Beuster, Presidium

Main topics

This conference will be devoted to interdisciplinary HBO therapy as well as to basic science and to aspects of nursing in hyperbaric medicine.

Hyperbaric medicine topics:

- Application of HBOT in burn injury, critical care, neurological disorders,
- oncology, paediatrics, radiotherapy and traumatology
- Critical incidence reporting – discussion of cases
- Basic research
- Nursing the HBO therapy patient – a challenge?

Diving medicine topics:

- Advances in diving research
- Validation of decompression profiles
- Restart of diving after neurological DCI
- Special environmental conditions: high altitudes, cold water
- Diving with the handicapped

Call for abstracts and deadlines:

Submission of abstracts: 4 May 2008

Early registration: 1 June 2008

Submission of full papers: 22 June 2008

Detailed instructions for abstract submission (electronic only) and publication may be found on the conference website: <<http://www.eubs2008.org>>. Peer-reviewed abstracts will be published as a supplement to the journal *Diving and Hyperbaric Medicine* in December. Participants are also invited to submit their full manuscript for consideration of publication in *Diving and Hyperbaric Medicine*. Student travel grants are available and participation in the Zetterstrom Poster Award is encouraged. Further information is available on the website.

Satellite meetings, social events, and prices are shown on the conference website.

Venue: Main Auditorium at Graz University Hospital, Auenbrugger Platz 36

Hotel Reservation: via Graz Tourism Agency, available via the conference website <<http://www.graztourismus.at>>

E-mail: <info@graztourismus.at>

Phone: +43-(0)316-807547

Refer to EUBS 2008 when booking, please. Please do not hesitate to contact us if you need further assistance:

Conference office: Martina Neuhold, Auenbrugger Platz 29, Graz

Office phone: +43-(0)316-385-81923 or +43-(0)664-859-6146

Minutes of the EUBS General Assembly held on 14 September 2007, Sharm el Sheikh, Egypt

The President, Alf Brubakk, welcomes the members. The agenda and the minutes from the General Assembly 2006 are accepted, followed by the report of the General Secretary of the 33rd Annual Conference, Dr Adel Taher. There were 230 paying members, 22 guests and 320 participants to the gala dinner all in all, from 31 different countries. The meeting is considered a success.

In his presidential report, Alf Brubakk states that there has been a 10% increase in membership up to an actual total of 350 members. The members should, however, increase their participation in the Society's affairs, for instance only 20% have taken part in the elections of the new Vice President and new Member at Large. Maybe this is due to the fact that the Society should do more for the members than only organising annual meetings and publishing the *EJUHM*. There is a lot of good research done, the DAN group, the Brubakk group, Uwatec, Suunto, EDTC, etc. The role of the Society is to participate in this, to educate new young researchers in order to facilitate its future in diving and hyperbaric medicine. Research in diving medicine can have an impact on other science, for instance the research done in Norway showing that a single exercise before diving can diminish the number of circulating bubbles has an impact on sports medicine in general. EUBS has to expand on this. One step in this direction could be the expansion of our journal.

Peter Mueller, editor in chief of the *EJUHM*, announces the merger of *EJUHM* with *Diving and Hyperbaric Medicine*, formerly the SPUMS Journal (South Pacific Underwater Medicine Society). *EJUHM* will publish its final edition this year. After that, EUBS will collaborate with SPUMS, and maybe others, i.e., Asian societies, to expand *Diving and Hyperbaric Medicine*, the ultimate goal being to be rapidly indexed in Medline in order to attract more quality articles. The major focus of this new journal will remain diving medicine, as some HBOT papers should rather go into the journals of the corresponding medical specialties. Peter Mueller also reminds the members that this journal is their journal and that they need to submit quality material to it to make it a success. An increase of the membership fee, which amount is not yet known, will be necessary. The Executive Committee of the EUBS will write a letter of intention to SPUMS for a trial period of two years. Comments from the audience encourage this proposal. Alf Brubakk asks the members to send more quality articles in order to increase the chances of being indexed in Medline.

Peter Germonpré, webmaster of the Society's home page, reports some improvements aiming to ease communication between members and to increase the attractiveness of the site. A personal password will be attributed to each member allowing them to vote electronically and to update their personal data. The membership directory will be available

online and a large English database of scientific articles, compiled and indexed by the German Hyperbaric and Diving Society, will be offered to the members. These modifications should be available by the end of this year. The inclusion of the proceedings of the annual meetings in PDF format will begin, starting with this year's material. The addition of previous proceedings is also planned. All members are requested to send their e-mail address to Tricia Wooding (patriciaawooding@btinternet.com) immediately if they are interested in the new features of the Society's website.

The financial statement of the Society is depressing. Even though there is no audit report at this time, the account has been audited and found to be correct. The Society is poor with only £3,220 in our account.

This year the Zetterstöm award has been won by Dr Emmanuel Gempp and co-workers for their work entitled: Preventive Effect of Pre-dive Hydration on Bubble Formation. The poster has been awarded for its good methodology and immediate practical relevance to the field.

Alf Brubakk thanks Jacek Kot for his service to the Society as Member at Large.

The new Vice President and Member at Large of the Society are respectively Dr Peter Germonpré from Belgium and Dr Phil Bryson from the UK.

Next annual meetings are to be held in Graz (September 2008) and the UK (2009). Greece has cancelled its candidature for 2010 and will be replaced by either Turkey or Poland.

Some general comments from the audience express the need for more discussion time after the presentations. The organising committee expresses disappointment about the bad payment ethic of members, for congress fees as well as for membership fees.

Dr Adel Taher and his crew of volunteers are congratulated for an excellent congress and venue.

Jörg Schmutz, Secretary

Call for candidates: Member at Large 2008–2011

Armin Kemmer ends his term as Member at Large this year.

All members of EUBS wishing to propose a candidate are invited to send a short presentation and CV of their candidate to the Secretary of EUBS, Joerg Schmutz (joerg.schmutz@hin.ch), copy to the President, Alf Brubakk (alf.o.brubakk@ntnu.no).