

# Hyperbaric medicine in Croatia - a review and perspectives

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## HYPERBARIC MEDICINE IN CROATIA – A REVIEW AND PERSPECTIVES

*Nadan M Petri, Hasan Kovačević, Dejan Andrić*

### SUMMARY

A short review of the most important achievements in hyperbaric medicine in the world and in the Republic of Croatia is given. For the first time, the Croatian List of Approved Uses is presented, although it has never been formally confirmed by the National Health authorities. The authors advocate the idea of a network of monoplace and multiplace hyperbaric chambers to cover the country.

**Key words:** hyperbaric medicine, hyperbaric oxygen, indications for HBO

### SAŽETAK

U radu se daje kratak prikaz najvažnijih dostignuća hiperbarične medicine u svijetu i u Hrvatskoj. Prvi puta objavljuje se Hrvatska lista prihvaćenih indikacija, iako je formalno nije potvrdio Republički fond zdravstvenog osiguranja i zdravstva. Autori zagovaraju ideju o formiranju mreže jednomjernih i višemjernih hiperbaričnih komora, koja bi trebala pokriti čitavu zemlju.

**Ključne riječi:** hiperbarična medicina, hiperbarični kisik, indikacije za HBO

### INTRODUCTION

Hyperbaric medicine is no longer a witchcraft or a method in search of diseases.<sup>1,2</sup> The essential readings on hyperbaric medicine could be found elsewhere.<sup>3,4</sup> After more than 50 years of experience hyperbaric medicine has become a modern method accepted worldwide, of proved efficacy, respected and needed. However, it has not been developing in the Republic of Croatia in the way we consider necessary and adequate. There are at least two main explanations:

1. Hyperbaric chambers are available at a cost that has been a major problem to the majority of general hospitals and clinical centers in our country.

2. Hyperbaric medicine has not been given an important role in the medical curriculum and training of medical students and residents.

At this time there are only four specialists in Croatia trained in undersea and hyperbaric medicine, and only one hyperbaric medical facility at the Undersea and Hyperbaric Medicine Depart-

ment of the Naval Medical Institute of the Croatian Navy in Split (UHMD NMI), with a large two-lock walk-in chamber. To our knowledge, there are no other facilities ready and able to provide hyperbaric medical treatment, except one monoplace hyperbaric chamber in Pula, available for diving emergencies only. Most of the experience in hyperbaric medicine in Croatia has been gathered at the UHMD NMI during the past 25 years. It is known only to few members of Croatian medical community, mainly in Split and Rijeka, that some major achievements in hyperbaric medicine, a part of medical heritage of the world, originate in Croatia. One is the work done by Račić on peripheral facial nerve palsy and the effect of hyperbaric oxygen (HBO) in its treatment<sup>5-7</sup> and the other is the work done by Bojić on glaucoma, retinopathy, and ischemic optic nerve neuropathy and HBO as a method of treatment.<sup>8-11</sup> These results are quoted by senior authors in the most prominent medical papers and books.<sup>3,12</sup> We put HBO high on the list of medicines when Bell's palsy and open angle glaucoma are concerned, while the results on ischemic optic nerve disease and retinopathy are promising. Perhaps the first prospective double-blind clinical study that has ever been performed on the influence of HBO on arterial occlusive disease of the lower limb was done by Kovačević.<sup>13-16</sup> But, surprisingly enough, it

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seems that HBO is not recognized in Croatia at all.<sup>17</sup> It should be emphasized that there has never been a single, not even a minor, accident in the hyperbaric medical facility at the UHMD NMI for over 25 years. However, there are only limited possibilities in Croatia to do basic research in biochemistry of HBO (free radicals, reperfusion injury, oxygen tissue and cell partial pressure level, etc.), thus limiting research to clinical studies, only.

### HYPERBARIC MEDICINE IN THE WORLD TODAY

According to the available data, there are some 2,100 hyperbaric chambers in the world. More than 1,200 are in the territory of the ex-Soviet Union and the number is rising yearly.<sup>18</sup> It is assumed that there are more than 5,000 monoplace chambers currently in use around the world.<sup>19</sup> The number of chambers per million inhabitants is presented in Figure 1. At this time there are eight medical journals and three newsletters publishing articles mainly in the field of hyperbaric medicine. Also, there are seven national and international medical societies and two agencies in the United States for certification in the specialty of hyperbaric medicine.<sup>1,20</sup> Since hyperbaric medicine was recognized as a specialty recently (United States, only), most of the contemporary experts in hyperbaric medicine have another primary medical specialty. Although the achievements in hyperbaric medicine are presented annually in a vast number of publications, medical journals, books, handbooks, and workshop reports, what really makes a method effective is its applicability. Lists of indications and approved uses in the world today differ from country to country. The most famous and perhaps the most strict one is, in our opinion, that of the

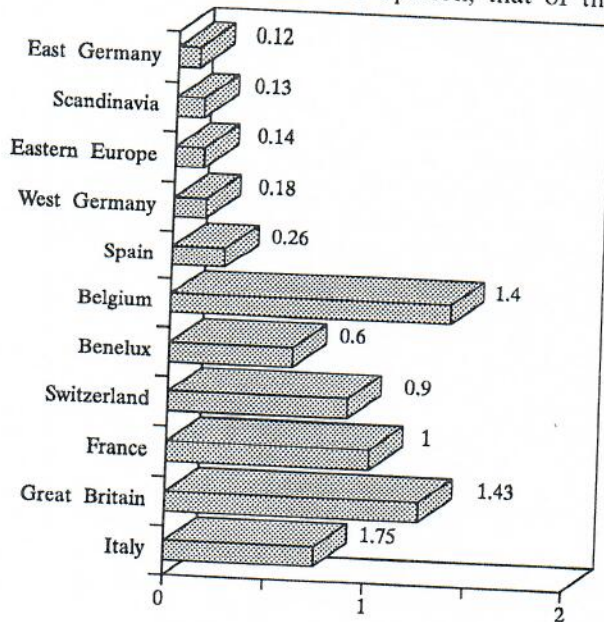


Figure 1. Number of chambers per million inhabitants

Undersea and Hyperbaric Medical Society (UHMS), Bethesda, Maryland, USA.<sup>21</sup> To our knowledge, there are some other lists, too: List of the American College of Hyperbaric Medicine, List of the Chinese High Pressure Oxygen Committee, List of the Japanese Society for Hyperbaric Medicine, and the list based on the USSR Ministry of Health Decree.<sup>22</sup> Reading all of them inevitably brings up certain suspicion, criticism or disagreement (Tables 1 to 5). It is up to the reader to evaluate the rationale for all of the indications listed. As for us, we have asked ourselves so many times whether to try or not to do something that others had already tried and reported success.

Table 1. List of Approved Uses of the Undersea and Hyperbaric Medical Society (Revised 1989)

1. Air or gas embolism
2. Carbon monoxide poisoning and smoke inhalation
3. Carbon monoxide complicated by cyanide poisoning
4. Crush injury, compartment syndrome, and other acute traumatic ischemias
5. Decompression sickness
6. Enhancement of healing in selected problem wounds
7. Exceptional blood loss (anemia)
8. Necrotizing soft tissue infections (subcutaneous tissue, muscle, fascia)
9. Osteomyelitis (refractory)
10. Radiation tissue damage (osteoradionecrosis)
11. Skin grafts and flaps (compromised)
12. Thermal burns

Table 2. List of indications for hyperbaric oxygen of the American College of Hyperbaric Medicine (1983)

Emergency indications:

1. Air embolism
2. Decompression illness
3. Burns
4. Carbon monoxide poisoning
5. Cerebral edema
6. Closed head injuries
7. Crisis of sickle cell anemia
8. Cyanide poisoning
9. Exceptional blood loss anemia
10. Blast injury
11. Gas gangrene
12. Hydrogen sulfide poisoning
13. Near drowning
14. Near electrocution
15. Near hanging
16. Peyote poisoning
17. Severed limbs
18. Smoke inhalation
19. Ileus

Specific neurologic indications for hyperbaric oxygen:

1. Air embolism
  - a) Decompression induced
  - b) Iatrogenic
2. Cerebral edema
  - a) Toxic encephalopathy
  - b) Vasogenic
  - b) Traumatic
3. Spinal cord contusion



- a) Physiological transection
- b) Partial motor or sensory loss
- 4. Early organic brain syndrome
  - a) Small vessel disease
- 5. Stroke
  - a) Acute
  - b) Chronic
- 6. Vegetative coma
  - a) Closed head injury
  - b) Hypoxic encephalopathy
- 7. Multiple sclerosis:
  - a) Acute
  - b) Relapsing/remitting
  - c) Chronic progressive
- 8. Cranial nerve syndromes
  - a) Trigeminal neuralgia
  - b) Optic neuritis
  - c) Vestibular disorders
  - d) Sudden deafness
  - e) Brain stem syndrome
  - f) Retinal artery occlusion
- 9. Peripheral neuropathy
- 10. Charcot Marie's Tooth Dis.
- 11. Radiation myelitis
- Orthopedic indications for hyperbaric oxygen
  - 1. Crush injuries
  - 2. Soft tissue swelling
    - a) Traumatic
    - b) Cellulitis (infection/mixed flora)
  - 3. Compartment syndrome
  - 4. Acute necrotizing fasciitis
  - 5. Clostridial myonecrosis
  - 6. Severed limbs and digits
  - 7. Acute and chronic osteomyelitis
  - 8. Bone grafting
  - 9. Fracture/non-union
  - 10. Tendon and ligament injuries, post surgical repair
  - 11. Delayed wound healing
  - 12. Stump infections
  - 13. Edema under cast
- Miscellaneous indications:
  - 1. Peripheral vascular ulcer
    - a) Arterial
    - b) Decubitus
    - c) Neuropathy related
    - d) Venous
  - 2. Gangrene (wet/dry)
  - 3. Buerger's disease
  - 4. Frostbite
  - 5. Diabetic retinopathy
  - 6. Retinal artery occlusion
  - 7. Retinal vein thrombosis
  - 8. Lepromatous leprosy
  - 9. Migraine
  - 10. Pneumatosis cystoides intestinalis
  - 11. Pseudomembranous colitis
  - 12. Rheumatoid arthritis (acute), sclerodermia
  - 13. Sick cell crisis and hematuria
  - 14. Peptic ulcer
  - 15. Myocardial infarction
  - 16. Post-cardiotomy low output failure
  - 17. Radiation cystitis and enteritis
  - 18. Refractory mycoses

Table 3. List of indications for hyperbaric oxygen in the ex-USSR (USSR Ministry of Health Decree, 1975)

I-GENERAL REMARKS

- (a) Hyperbaric oxygen therapy is absolutely suitable for the following indications:
  - 1-Carbon monoxide poisoning
  - 2-Hemoglobin poisoning
  - 3-Gas gangrene
  - 4-Gas embolism
- (b) HBO treatment is recommended in association with other treatments in the following conditions:
  - 1-Acute and chronic difficulties with the arteries of the lower limbs
  - 2-Chronic coronary ischemia
  - 3-Peritonitis
  - 4-Hemoglobin poisoning by carbon monoxide and by barbiturates
  - 5-Post hemorrhage
  - 6-Anaerobic infections
  - 7-Newly born and premature babies hypoxia
  - 8-After radiotherapy and prior to surgery in lung, mouth mucosa, and uterus cancers
  - 9-Pre-surgery preparation for cardiac acquired or congenital malformations, to help blood circulation in high risk surgery
  - 10-Preparation for surgery on the aorta and its cephalic branches
  - 11-Preparation for cardiac malformation surgery
- (c) The wide use of monoplace chambers in USSR led to research in the HBO Department in the Lenin Institute Medical Center. After setting up the list of indications, the list was submitted for amendments to 68 experts from the different HBO centers of the USSR.
- (d) No mention is made about the use of multiplace chambers for surgery. This is due to the absence of multiplace chambers in the USSR.

II-INDICATIONS FOR THE USE OF HBO

- 1. Vascular pathology
  - 1.1. Arterial obstruction of the limbs before and after surgery (embolism, traumas, thrombosis)
  - 1.2. Obstructive arteriopathy of the limbs
  - 1.3. Arteriosclerosis
  - 1.4. Gas embolism in the blood vessels
  - 1.5. Ulcers caused by defective blood circulation
- 2. Heart pathology
  - 2.1. Heart strain
  - 2.2. Heart rhythm disturbances
    - 2.2.1. Irregular heart beat
    - 2.2.2. Paroxysmal extrasystole
  - 2.3. Cardiac insufficiency
    - 2.3.1. Decompensation in acquired cardiac malformations
    - 2.3.2. Cardiosclerosis decompensation
    - 2.3.3. Cardiac insufficiency after heart surgery
  - 2.4. Heart contraction disturbances
  - 2.5. Cardio-pulmonary insufficiency
- 3. Lung pathology
  - 3.1. Lung abscess before and after surgery
  - 3.2. Nonspecific chronic lung affections with cardio-pulmonary insufficiency signs
- 4. Gastrointestinal pathology
  - 4.1. Stomach and duodenal ulcers
  - 4.2. Intestinal occlusion
  - 4.3. Posthemorrhagic syndrome
- 5. Liver pathology
  - 5.1. Acute viral hepatitis

- 5.1.1. With encephalitis disturbances (stages 1 and 2)
- 5.1.2. Without encephalitic disturbances but with rapid evolution
- 5.2. Liver cirrhosis
- 5.3. Mechanical jaundice
- 5.4. Hepatic insufficiency after resuscitation
- 5.5. Toxic hepatitis (hepatotropic poisons)
- 6. Central nervous system pathology
  - 6.1. Brain vessels gas embolism
  - 6.2. Brain ischemia
  - 6.3. Cranial trauma
  - 6.4. Posthypoxic encephalopathy
  - 6.5. Botulism
  - 6.6. Cervical spinal cord trauma
- 7. Eye pathology
  - 7.1. Acute retinal ischemia
  - 7.2. Retinal dystrophy
  - 7.2. Diabetic retinopathy
  - 7.4. Optic neuritis by methanol intoxication
- 8. Endocrine pathology
  - 8.1. Diabetic arteriopathy
  - 8.2. Diabetic ulcers and polyneuritis
  - 8.3. Toxic goiter
- 9. Facial and maxillar pathology
  - 9.1. Paradontosis
  - 9.2. Facial phlegm
  - 9.3. Maxillary osteomyelitis
  - 9.4. Necrotic gingivitis and stomatitis
  - 9.5. Facial actinomycosis
- 10. Bone pathology
  - 10.1. Fractured limbs with blood circulation disturbances
  - 10.2. Fractures in an arteriopathic or diabetic patient
  - 10.3. Delayed fracture solidification
- 11. Obstetrics pathology
  - 11.1. Abortion by placental ischemia
    - 11.1.1. Threats of abortion of endocrine origin
    - 11.1.2. Placental hypoxia
    - 11.1.3. Fetal hypoxia
    - 11.1.4. Pregnancy neuropathy (stage 1 and 2)
    - 11.1.5. Pregnancy with immunological conflict
  - 11.2. Pregnancy complications by extragenital pathology
  - 11.3. Pregnant or delivered mothers in critical state
    - 11.3.1. Coma after eclampsia
- 12. Newly-born babies pathology
  - 12.1. Asphyxia during delivery
  - 12.2. Brain-blood circulation disturbances
  - 12.3. Newly-born babies hemolysis
  - 12.4. Ulcero-neurotic enterocolitis
  - 12.5. Phlegm
- 13. General surgery infections
  - 13.1. General septic abscess in spite of incision
  - 13.2. Infectious peritonitis with surgical removal of initial lesions
- 14. Wound pathology
  - 14.1. Clostridial infection
  - 14.2. Wound abscess in spite of drainage
  - 14.3. Prophylactic treatment of wound infected after open trauma
  - 14.4. Granular wound
  - 14.5. Wound with superficial burn
  - 14.6. Post-surgery wound
- 15. Exogenous poisoning
  - 15.1. Carbon monoxide poisoning
  - 15.2. Poisoning of the hemoglobin
  - 15.3. Cyanide poisoning

- 15.4. Chloroxide poisoning
- 15.5. Phospho-organic insecticides poisoning (Carbophosphorus)

Table 4. Chinese High Pressure Oxygen Committee List of Indications (1982)

- Class 1 - Main indications
  - 1. Carbon monoxide poisoning
  - 2. Gas gangrene
  - 3. Decompression sickness
  - 4. Air embolism
  - 5. Acute central retinitis
  - 6. Grafts
  - 7. Gas poisoning
  - 8. Hypoxic disorders of the brain
  - 9. Drug intoxication, e.g., barbiturates
- Class 2 - Adjunctive therapy
  - 1. Severed limbs: reconstructive surgery
  - 2. Peripheral circulatory failure
  - 3. Coronary artery disease: angina, myocardial infarction
  - 4. Central retinal artery occlusion
  - 5. Ischemic cerebral disease
  - 6. Thrombo-embolic disorders
  - 7. Sudden deafness
  - 8. Peripheral circulatory insufficiency
  - 9. Burns
  - 10. Meniere's syndrome
  - 11. Late sequelae of carbon monoxide poisoning
  - 12. Non specific viral hepatitis
  - 13. Chronic osteomyelitis
  - 14. Non-union of fractures
  - 15. Osteoradionecrosis and soft tissue damage
  - 16. Gastric and duodenal ulcers
  - 17. Paralytic ulcers
  - 18. Cardiopulmonary resuscitation
  - 19. Cerebral edema
  - 20. Shock, including postoperative shock in heart surgery
- Class 3 - Research indications
  - 1. Acute cerebrovascular disorders
  - 2. Chronic peripheral vascular disease
  - 3. Chilblain
  - 4. Tetanus
  - 5. Pityriasis rosea
  - 6. Tuberculus erythema
  - 7. Hemigrania and late sequelae of head injury
  - 8. Postoperative cerebral dysfunction
  - 9. Severe neurasthenia
  - 10. Myasthenia
  - 11. Aging
  - 12. Spinal cord and peripheral nerve injury and inflammation
  - 13. Bronchial asthma
  - 14. Cancer therapy combined with radiation
  - 15. Oral inflammatory disease
  - 16. Nerve deafness

Table 5. Japanese Society for Hyperbaric Medicine List of Indications for hyperbaric oxygen (1985)

- Emergency (acute) indications:
- 1. Acute carbon monoxide and other gas-induced intoxication, including delayed intoxication
  - 2. Gas gangrene
  - 3. Air embolism and decompression sickness
  - 4. Acute peripheral vascular disorders:
    - a) Severe burn injury and frostbite



- b) Combined with large crush injury or massive vascular damage
- 5. Shock
- 6. Myocardial infarction and other coronary insufficiencies
- 7. Consciousness disorders and brain edema after brain embolism or severe cranial injury
- 8. Acute and severe hypoxic disorder of brain
- 9. Paralytic ileus
- 10. Acute obstructive disorders of the retinal artery
- 11. Sudden deafness
- 12. Severe spinal cord disorders
- Non-emergency (chronic) indications
- 1. Malignant neoplasms, combined with radiation or chemotherapy
- 2. Peripheral circulatory disorders with refractory ulcers
- 3. Skin grafts
- 4. SMON (Subacute myelo-optic neuropathy)
- 5. Motor paresis, as the later sequelae of cerebrovascular attack, severe cranial injury or craniotomy
- 6. Delayed syndromes in carbon monoxide intoxication
- 7. Spinal cord neuropathy
- 8. Osteomyelitis and radiation necrosis

Table 6. Croatian List of Approved Uses - List of indications for hyperbaric oxygen as accepted at the Naval Medical Institute of the Croatian Navy

- Decompression sickness
  - Acute forms (Type I and Type II)
  - Dysbaric osteonecrosis
- Arterial gas embolism
- CO poisoning (smoke and cyanide inhalation)
- Radiation tissue injury
- Compromised skin grafts and flaps
- Sudden deafness of different origin
- Open angle glaucoma
- Bell's palsy
- Acute traumatic ischemia
  - Crush syndrome
  - Compartment syndrome
  - Frost-bite injury
- Clostridial myonecrosis (gas gangrene)
- Necrotizing soft tissue infections
- Problem wounds
- Acute and chronic arterial insufficiency of different origin
  - Atherosclerosis (2nd to 4th degree, including diabetic angiopathy)
  - M. Burger
  - Syndrome and M. Raynaud
  - M. Crohn
  - Allergic vasculitis
  - M. Sudeck
- Thermal burns
- Refractory osteomyelitis
- Exceptional blood loss

\* For practical reasons only the old classification of diving related dysbaric diseases has been used. New classification recognizes Decompression Illness and Barotrauma. For further reading please consult Gorman D. F. A proposed classification of the decompression illness. In: Francis TJR, Smith DJ, eds. Describing decompression illness. Proceedings of the 42nd Undersea and Hyperbaric Medical Society Workshop. Bethesda, MD, UHMS, 1991;42:6-9.

### IS THERE THE CROATIAN LIST OF APPROVED USES?

Such a list does not formally exist. At this time it is not quite clear who in the Republic of Croatia should confirm it. This issue brings up two aspects of the problem: financial and scientific. During the last 25 years, we at the UHMD NMI have been gathering experience, using experience of the others, and working, though slowly and cautiously, but constantly. Table 6 presents a summary of the former, and could be understood as the Croatian List of Approved Uses of HBO. The list has not been confirmed by the state authorities, but this is expected in the near future.

### PERSPECTIVES OF HYPERBARIC MEDICINE IN CROATIA

There will be no perspectives at all without investing in future facilities. In our opinion, they are absolutely necessary in Zagreb and Rijeka, major university centers in the country. General hospitals in Pula, Zadar, Šibenik, Dubrovnik, Karlovac, Sisak, Varaždin, Bjelovar, Slavonki Brod, Osijek, and special hospitals for orthopedic surgery and traumatology in Lovran and Biograd na moru should have monoplace chambers at least (Figure 2).

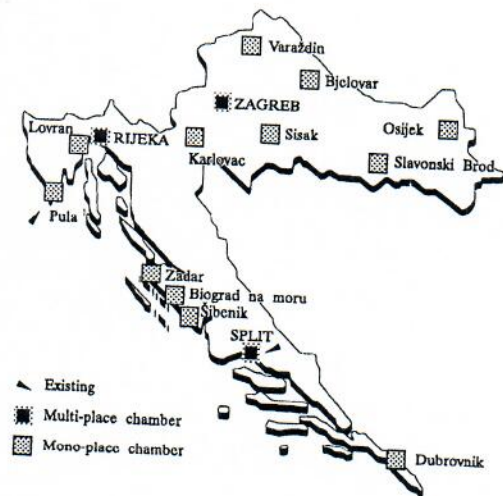


Figure 2. Possible hyperbaric chambers network in Croatia

It is considered essential today that a hyperbaric chamber should always be at the site if surgery with a certain amount of risk of arterial gas embolism is to be performed, not to mention open-heart surgery.<sup>23</sup> This major project could be accomplished at present time at a price of approximately two million US dollars. In the coastal area it would attract recreational divers, since diving would be much safer. When general well-being of the people and cost-benefit ratio are taken into consideration, it is an entirely reasonable price. The financial rationale is beyond the scope of this paper. Our recommendation is primarily



based on the clinical experience, but we do support the opinion that clinically based hyperbaric medicine programs should be carefully chosen, understanding that there might be other priorities in a country in which the images of war are still on the front pages.<sup>24</sup> Nevertheless, during the Serbian aggression we have been treating numerous war casualties before and after surgery, in cases when gas gangrene or anaerobic infection were suspected or evident, and to enhance wound healing. Casualties have been coming mainly from the battlefields in the vicinity of Split, but also from the field hospitals from relatively distant battlefields. Unfortunately, an unknown number of casualties from distant battlefields remained untreated. Recently, an interesting idea has been brought up, according to which monoplace chambers could be operated in primary health care centers, too, if such a need were recognized, and found reasonable (Kovačević H. and co-workers, in preparation). Another network of monoplace chambers would, in this way, cover the places not mentioned in this article. UHMD NMI could serve as a basis for the future network, since it is the only institution in the country experienced in HBO, and ready to accept resident physicians for training in hyperbaric medicine.

## CONCLUSIONS

Hyperbaric medicine in Croatia does exist although there is only one multiplace hyperbaric chamber in the country of 4.6 million inhabitants, what is obviously not enough. For 25 years hyperbaric medical facility in Split has been operating successfully and has made some major contributions to the world medical heritage. The Croatian List of Approved Uses proved its validity through the years, although it has never been formally recognized by the national health authorities. Two major university centers (Zagreb, Rijeka) have been, so far, functioning without hyperbaric medical facilities. There is an obvious and immediate need to change such practice. Development of basic network of hyperbaric chambers should be started without further delay and hesitation, and monoplace chambers should be provided to general hospitals statewide. This appears to be an expensive task, but it has several benefits. Hyperbaric medicine should be given more important place in the curriculum at medical schools in Croatia. We consider that not only should it be recognized as a specialty but it should also become a part of medical training of residents at least in surgery and anesthesiology.

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