Short communication

The prevalence of electrocardiogram abnormalities in professional divers

Ali Erdal Gunes and Maide Cimsit

Abstract

(Gunes AE, Cimsit M. The prevalence of electrocardiogram abnormalities in professional divers. *Diving and Hyperbaric Medicine*. 2017 March;47(1):55-58.)

Background: The underwater environment presents physiological challenges for the cardiovascular, renal and pulmonary systems. Increases in external hydrostatic pressure reduce the capacity of the venous compartment and cause blood to move toward the lung. The aim of this study was to evaluate retrospectively electrocardiographic (ECG) changes in a cohort of professional divers.

Methods: Between January 2009 and January 2012, 225 randomly selected professional divers, 204 male (91%) and 21 female (9%) attended our clinic for their biannual diving medical assessment. Their ECG records were evaluated retrospectively.

Results: The most common ECG abnormality observed was incomplete right bundle branch block (IRBBB) in 30 divers (13.3%). Eleven divers (4.9%) showed right QRS axis deviation (seven with IRBBB). Six divers had a sinus tachycardia; in four divers there was early repolarization; three divers had ventricular extrasystoles; one diver had ST elevation in lead V3; there was one with sinus arrhythmia and another with T-wave inversion in leads V2, V3 and aVF. These ECG changes were evaluated retrospectively by a cardiologist who made various recommendations for further review including bubble-contrast echocardiography for IRBBB.

Conclusions: No serious ECG abnormalities were identified, but IRBBB should be further investigated because of its association with persistent (patent) foramen ovale. Rapid cardiological review of ECGs could be achieved using modern communications technology, such as telecardiography, and further clinical investigations directed by specialist recommendation arranged promptly if indicated.

Key words

Diving at work; Electrocardiography; Health status; Fitness to dive; Diving research

---

Introduction

The underwater environment presents physiological challenges, particularly for the cardiovascular, renal and pulmonary systems.[1] Immersion reduces the capacity of the venous compartment and causes blood to move toward the lung.[2] Immersion also results in an increased cardiac output, a rise in stroke volume and increased arterial pulse pressure, leading to fluid loading on the left heart.[1] The increased pulmonary blood volume results in increased residual volume and reduced vital capacity.[3] Increasing environmental pressure reduces systolic left and right ventricular function and decompression may cause endothelial dysfunction.[4] Because of their sustained exercise, professional divers create adaptations to the underwater environment, include the myocardium, which may be associated with electrocardiographic (ECG) changes.[5] Pathological ECG findings may offer important clues about structural abnormalities of the heart, e.g., left ventricular hypertrophy, persistent (patent) foramen ovale (PFO) and the possible causes of sudden death in divers.[6]

In Turkey, occupational divers are required to undergo bi-annual examination conducted by physicians who specialize in underwater medicine. This includes laboratory tests and ECG recordings. The aim of this study was to evaluate retrospectively the ECG findings of a cohort of professional divers assessed in our clinic.

Method

The study was conducted in the Istanbul University Faculty of Medicine Underwater and Hyperbaric Medicine Clinic between 01 January 2009 and 31 January 2012. Permission was obtained from the Directors of the Department of Underwater Clinical Medicine to conduct the research. The aim of the study was explained to the divers who gave written consent for their information to be used for medical research purposes in this and other potential studies.

The case records were selected by stratified randomisation from a larger number over that time frame. The records of 225 professional divers, 204 male (91%) and 21 female (9%), aged between 18 and 46 years, presenting to the clinic for routine biannual examination were evaluated retrospectively. Demographic parameters were stored in a Microsoft Excel 2010 database and simple descriptive statistical evaluation was performed using the SPSS 17.0 programme (SPSS Inc., Chicago, IL, USA). A standard 12-lead digital ECG (EDAN SE-1200 Express 12-channel ECG) was recorded after the diver had rested supine for at least three minutes. Standard diagnostic criteria were used for the identification

Table 1
Anthropometric characteristics of 225 professional divers

Characteristic	Mean	(SD)
Males	204	
Females	21	
Age (y)	26.5	(5.7)
Height (cm)	177	(7.2)
Weight (kg)	78	(10.6)
Body mass index (kg·m^{-2})	23.4	(2.8)
Diving experience (y)	11	(2.7)

of ECG abnormalities.[8–10] Abnormal ECGs were assessed retrospectively by a cardiologist.

Results

Table 1 summarises the demographics of the 225 divers. The most common ECG abnormality was incomplete right bundle branch block (IRBBB) in 30 divers (13.3%), 22 males and eight females. Eleven divers (4.9%, eight males) showed right axis QRS deviation; seven of these 11 were in the IRBBB group. Nine divers (4%) had sinus bradycardia. A number of other abnormal ECG findings were noted. These included six divers (2.7%) with sinus tachycardia, four divers with early repolarization, three with ventricular extrasystoles, a diver who had ST elevation in V3, a diver with sinus arrhythmia, and a diver who had a negative T-wave in V2, V3 and aVF. Table 2 summarises the types and frequency of the abnormal ECG findings.

RETROSPECTIVE CARDIOLOGICAL ASSESSMENT

Retrospective cardiological review of the abnormal ECGs resulted in a number of recommendations for further assessment. Firstly, it was suggested that IRBBB and right axis deviation should be referred for transthoracic bubble-contrast echocardiography. If indicated, trans-oesophageal bubble-contrast echocardiography and cardiac magnetic resonance imaging may be recommended as the next step. Pre-syncope and hypotensive episodes need to be evaluated in sinus bradycardia and, if insertion of a cardiac pacemaker is recommended, no diving permit is given. Systemic disease should be investigated for in sinus tachycardia. Where ventricular extrasystoles and ST and T-wave changes are present, investigation for ischaemic heart and valvular disease should be considered. Electrophysiological studies may be required for ventricular extrasystole. Table 2 also summarises the cardiologist's opinion of what further investigations were indicated.

Discussion

This was a retrospective study of a cohort of professional divers undergoing biannual medical clearance. According to the regulations for professional divers in Turkey, if abnormal findings are detected, they are not allowed to dive until further specialist assessment has been completed. For treatable abnormalities or those not considered having a diving safety impact, the diving permit can be obtained; otherwise, those divers with irreversible abnormalities cannot dive again.

Serious ECG abnormalities are important factors for sudden death.[7] The rate of IRBBB at 13.3% in this study is quite high. IRBBB in an ECG recording is usually a benign finding in asymptomatic healthy people.[8] The prevalence of IRBBB and RBBB is higher in men than it is in women, and increases with age in men.[9] There were too few women (mostly underwater technology college students and civil defense staff) in our study to allow us to assess any sex differences. In healthy, young college athletes, IRBBB was not predictive of any structural abnormalities of the myocardium.[10] In addition, a study on 134 asymptomatic middle-aged men with IRBBB found no increased risk for cardiovascular disease in a 20-year follow-up.[11] However, another study reported an increased risk of sudden death in patients with RBBB.[12]

Atrial septal defect (ASD) is the most frequent congenital

Table 2
Abnormal ECG finding in 225 professional divers and retrospective comments by a cardiologist regarding recommended follow-up; EPS – electrophysiological studies; IRBBB – incomplete right bundle branch block; MPS – myocardial perfusion scintigraphy; MRI – magnetic resonance imaging; NS – no suggestion; TEE – trans-oesophageal echocardiography; TTE – trans-thoracic echocardiography

Abnormal ECG finding			Cardiological assessment recommendations	
	n	(%)	1st stage	2nd stage
IRBBB	30	13.3	TTE (bubble-contrast)	TEE or Cardiac MRI
Right QRS axis deviation	11	4.8	TTE (bubble-contrast)	TEE or Cardiac MRI
Sinus bradycardia (<60)	9	4	Cardiac pacemaker if symptomatic	NS
Sinus tachycardia (>100)	6	2.6	Investigate for systemic disease	NS
Early repolarization	4	1.7	Risk for sudden cardiac death	NS
Ventricular extrasystoles	3	1.3	24-h Holter monitor; MPS or exercise testing	Coronary angiography; EPS
Negative T-waves	2	0.8	Exercise test; MPS	Coronary angiography
Sinus arrhythmia	1	0.4	NS	NS
ST elevation	1	0.4	Coronary angiography	NS

cardiac abnormality in adults.[13] Ostium secundum ASD is frequently associated with IRBBB and right QRS axis deviation.[14] Our study found right QRS axis deviation to be the second most common ECG finding (4.8%). In addition, PFO has a prevalence of 25% in the general population. The presence of a right-to-left shunt is often seen in divers with decompression sickness (DCS).[15] If defects in the atrial septum are not identified, the diver may be at increased risk of presenting acutely with DCS.[21]

Ventricular extrasystoles, observed in three patients, are seen in sleep apnoea, hypertension, and structural heart disease.[16] Further investigations are needed in these cases, such as 24-h Holter monitoring, and treatment as indicated. The uncommon finding of sinus tachycardia, the incidence of which was 2.6%, was attributed mainly to anxiety over the impact that the medical review might have on their diving career.

The changes observed in the ECGs of athletes are largely viewed as physiological adaptations.[17] The European Society of Cardiology divides ECG changes in athletic people into two categories: physiological changes that are associated with training and pathological changes that are not linked to training. Sinus bradycardia, which is the most commonly found ECG change seen in athletes, occurs as a result of increased parasympathetic activity.[18] Sinus arrhythmia is also found frequently in athletes.[17] As a result of abnormal repolarization, IRBBB is believed to be a right ventricular adaptation to strenuous exercise,[19] whereas complete RBBB is considered to be a pathological finding; evidence of right ventricular cardiomyopathy or Brugada syndrome.[19] T-wave inversion may indicate left ventricular hypertrophy, which could be either exercise-induced or pathological.[17] However, early repolarization is classified as a benign ECG change in elite athletes,[20] but can lead to a fatal incident in later life.[21]

Professional divers may work in deep waters where cardiopulmonary difficulties caused by the high ambient pressure and increased gas densities can lead to ventricular decompensation. Therefore, diagnosis of RBBB and other clinically important ECG changes in professional divers is important. In routine practice, expert ECG interpretation may be lacking in a diving medicine clinic and consideration should be given to routine ECG evaluation by a cardiologist. With modern technology, such as telecardiography via a smart phone or similar device, the ECG could be read within a few minutes.[22] The diving medical examination could then continue or be suspended pending further specialist assessment.

As a result of forwarding these cardiological opinions to the directors of the Department of Underwater Clinical Medicine, new protocols are being considered in the divers' clinic. Before medical clearance for diving is given, the ECG could be sent via smartphone for a cardiological opinion.

Conclusions

The ECG is necessary for early diagnosis of cardiovascular pathology. Changes that are not related to exercise should be carefully assessed cardiologically, possibly including transthoracic bubble-contrast echocardiography, exercise ECG testing and cardiac magnetic resonance screening. Bubble-contrast echocardiography may be particularly suitable in divers; it is a readily available, cheap, non-invasive technique. With modern technology, the ECG could be read by a cardiologist within a few minutes.

References

1 Pendergast DR, Lundgren CE. The underwater environment: cardiopulmonary, thermal, and energetic demands. *J Appl Physiol*. 2009;106:276-83.

2 Johansen LB, Jensen TU, Pump B, Norsk P. Contribution of abdomen and legs to central blood volume expansion in humans during immersion. *J Appl Physiol*. 1997;83:695-9.

3 Lundgren CEG. Respiratory function during simulated wet dives. *Undersea Biomedical Research*. 1984;11:139-47.

4 Marinovic J, Ljubkovic M, Breskovic T, Gunjaca G, Obad A, Modun D, et al. Effects of successive air and nitrox dives on human vascular function. *Eur J Appl Physiol*. 2012;112:2131-7.

5 Malhotra VK, Singh N, Bishnoi RS, Chadha DS, Bhardwaj P, Madan H, et al. The prevalence of abnormal ECG in trained sportsmen. *Med J Armed Forces India*. 2015;71:324-9.

6 Denoble PJ, Nelson CL, Ranapurwala SI, Caruso JL. Prevalence of cardiomegaly and left ventricular hypertrophy in scuba diving and traffic accident victims. *Undersea Hyperb Med*. 2014;41:127-33.

7 Groh WJ, Groh MR, Saha C, Kincaid JC, Simmons Z, Ciafaloni E. Electrocardiographic abnormalities and sudden death in myotonic dystrophy type 1. *N Engl J Med*. 2008;358:2688-97.

8 Eriksson P, Hansson PO, Eriksson H, Dellborg M. Bundle-branch block in a general male population the study of men born 1913. *Circulation*. 1998;98:2494-500.

9 Bussink BE, Holst AG, Jespersen L, Deckers JW, Jensen GB, Prescott E. Right bundle branch block: prevalence, risk factors, and outcome in the general population: results from the Copenhagen City Heart Study. *Eur Heart J*. 2013;34:138-46.

10 Le VV, Wheeler MT, Mandic S, Dewey F, Fonda H, Perez M, et al. Addition of the electrocardiogram to the preparticipation examination of college athletes. *Clin J Sport Med*. 2010;20:98-105.

11 Liao Y, Emidy LA, Dyer A, Hewitt JS, Shekelle RB, Paul O, et al. Characteristics and prognosis of incomplete right bundle branch block: an epidemiologic study. *J Am Coll Cardiol*. 1986;7:492-9.

12 Stojanovic VR, Peric S, Paunic T, Pavlovic S, Cvitan E, Basta I, et al. Cardiologic predictors of sudden death in patients with myotonic dystrophy type 1. *J Clin Neurosci*. 2013;20:1002-6.

13 Webb G, Gatzoulis MA. Atrial septal defects in the adult recent progress and overview. *Circulation*. 2006;114:1645-53.

14 Sung RJ, Tamer DM, Agha AS, Castellanos A, Myerburg RJ, Gelband H. Etiology of the electrocardiographic pattern of "incomplete right bundle branch block" in atrial septal defect: an electrophysiologic study. *J Pediatr*. 1975;87(6 Pt 2):1182-6.

15 Smart D, Mitchell S, Wilmshurst P, Turner M, Banham N. Joint position statement on persistent foramen ovale (PFO) and diving. South Pacific Underwater Medicine Society (SPUMS) and the United Kingdom Sports Diving Medical Committee (UKSDMC). *Diving Hyperb Med*. 2015;45:129-31.
16 Noheria A, Deshmukh A, Asirvatham SJ. Ablating premature ventricular complexes: justification, techniques, and outcomes. *Methodist Debakey Cardiovasc J*. 2015;11:109-20.
17 Kiss O, Sydó N, Vargha P, Édes E, Merkely G, Sydó T, et al. Prevalence of physiological and pathological electrocardiographic findings in Hungarian athletes. *Acta Physiol Hung*. 2015;102:228-37.
18 Sztajzel J, Jung M, Sievert K, Bayes De Luna A. Cardiac autonomic profile in different sports disciplines during all-day activity. *J Sports Med Phys Fitness*. 2008;48:495-501.
19 Kim JH, Noseworthy PA, McCarty D, Yared K, Weiner R, Wang F, et al. Significance of electrocardiographic right bundle branch block in trained athletes. *Am J Cardiol*. 2011;107:1083-9.
20 Tanguturi VK, Noseworthy PA, Newton-Cheh C, Baggish AL. The electrocardiographic early repolarization pattern in athletes. *Sports Med*. 2012;42:359-66.
21 Serra-Grima R, Doñate M, Álvarez-García J, Barradas-Pires A, Ferrero A, Carballeira L, et al. Long-term follow-up of early repolarization pattern in elite athletes. *Am J Med*. 2015;128:192. e1-192. e9.
22 Backman W, Bendel D, Rakhit R. The telecardiology revolution: improving the management of cardiac disease in primary care. *J R Soc Med*. 2010;103:442-6.

Funding and conflicts of interest: none

Submitted: 15 April 2016; revised 27 July, 07 October 2016, 09 January and 24 January 2017
Accepted: 01 February 2017

Ali Erdal Gunes[1], Maide Cimsit[2]

[1] Harran University, Faculty of Medicine, Underwater and Hyperbaric Medicine, Sanliurfa, Turkey
[2] Istanbul University, Istanbul Faculty of Medicine, Underwater and Hyperbaric Medicine, Istanbul, Turkey

Address for correspondence:
Assistant Professor Ali Erdal Gunes
Harran University School of Medicine, Faculty of Medicine
Department of Underwater and Hyperbaric Medicine
Osmanbey Campus, 63300,
Sanliurfa, Turkey
aerdalg@gmail.com