

South Australian diving-related deaths 2001–2002. A coroner's inquiry

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Key words

Deaths, scuba, case reports, medical conditions and problems, coroner's findings

Abstract

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Nine recreational diving-related deaths occurred in South Australia in a twenty-month period (2001–2). Five of these deaths were associated with medical conditions that were incompatible with safe diving: a body mass index >30, cardiomyopathy, asthma, lung bullae, pleural adhesions, poor physical fitness and controlled cardiac failure. Because of the similarities in these deaths they were the subject of a single coroner's inquest and the findings are presented.

Introduction

Nine diving-related deaths occurred in South Australia over a twenty-month period. Five of these deaths were associated with medical conditions that were incompatible with safe diving, such as a body mass index (BMI) of greater than 30 kg.m⁻², cardiomyopathy, asthma, lung bullae, pleural adhesions, poor physical fitness and controlled cardiac failure, and were the subject of a coroner's inquest. A sixth death is reported in a separate case report.¹ The seventh death was that of an obese man in his 50s, who died on his first dive on water entry with no submersion. His death was not the subject of a coroner's inquiry. Another death was due to a shark attack involving a professional scallop diver. The ninth was the death of a bystander involved with the resuscitation of one of the other divers; he was shown to have a coarctation of the aorta at post mortem.

The five deaths that were the subject of a coroner's inquest are described in detail here and the Coroner's recommendations presented. Further details of these deaths can be found on the South Australian Coroner's web site.² Each death will be presented in order of occurrence and diving details are quoted from the Coroner's reports.² The author attended all post mortems and supplied 'expert' witness evidence at the inquest. The South Australian State Coroner requires the presence of a suitably qualified medical practitioner in diving medicine to be present at all post mortems involving diving deaths.

Death 1

The deceased was a 44-year-old female doing a 'diving refresher' course. She had passed her diving medical, which was performed by a medical practitioner with an 'interest in diving medicine'. Of note in this case was that two diving medical forms were presented, one in which the deceased ticked 'chest problems' and the other submitted later to the doctor where 'chest problems' was not ticked. Details from her medical notes obtained from a public hospital revealed that she had suffered from a pneumothorax in 1996 and

used salbutamol regularly for 'shortness of breath'.

Details of the dive are quoted from the Coroner's report.²

"We both left the boat at the same time,...met her at the rear of the boat. At that point she seemed a little stressed,...I asked her if she was okay to descend, she indicated that she wanted to go to the boat and she held onto the mermaid line, then I went to her and then I asked her again and she indicated with the okay signal that she was ready to go...I reconfirmed the okay signal and then we began our descent.

We went straight down under the boat to the bottom, to the wall where we were going to dive. We settled on the bottom, a depth of 20.7 metres...We communicated through the use of hand signals,...she was okay and ready to go and...we headed off and dived along the wall...We played with the seals and started looking for crayfish. Every time I looked back she was there behind me, just waiting for me.

At about an average time into the dive,...Jenny came to me, tapped me on the shoulder and...indicated she wanted to go up. I indicated could I stay and could she make it back okay on her own. She agreed that she could. We agreed on the direction of the boat, we couldn't see the boat but you didn't have to swim far before you could see the boat. I watched her head off and...I continued looking for crayfish.

About 10 to 15 minutes later I returned to the boat. I came directly up underneath the boat, and when I got to the surface, Angie, the crew member on the boat, asked me where Jenny was. I told her I thought she was on the boat. Angie thought she may have been over by the rocks, which were about 15 to 20 metres away because she thought she had heard somebody call for help. I carried my scuba unit onto the boat and then set off and snorkelled to the rocks area that Angie had indicated to me.

I was only a few metres from the rocks when I saw her on the bottom. I had to observe her for a couple of seconds to see if she was diving or not, she was laying on her back. No air bubbles were coming from her or

her equipment. On looking down I could not see the regulator hanging out of her mouth. I believe it was still in her mouth. I feel I would have noticed that straight away. I tried to dive down to her but not having a weight belt on I couldn't get down to her. She would have been in about 5 metres of water. Another person came to me and he was only on a snorkel as well and couldn't get down there.

Within a few minutes a scuba-equipped diver was there and brought her to the surface. She did not have the regulator in on the way to the surface. She was at the surface with all her gear on. I tried to inflate her BCD [buoyancy compensator device] with the low pressure inflator but it didn't appear to be working, I then tried manual inflation, I realised that was going to take too long so we ditched her weight belt immediately. I checked to see if she was breathing, and it was fairly obvious that she hadn't been. I then tried to start mouth to mouth. We started dragging her towards the boat and frequently giving her mouth to mouth. I couldn't find any indication of breathing. I couldn't check for a pulse as I had gloves on. It took about 5 minutes to get her to the boat. It took so long because we were trying to resuscitate her."

COMMENTARY ON DEATH 1

The relevant post-mortem findings are reported in Table 1. The deceased was diving in a group of three. When she was low on air she indicated to the dive master with her gauge and then, with the instructor's knowledge, ascended alone. This is contrary to safe diving practice.^{3,4} Also noted in the narrative was that a boat member thought she had heard a cry for help but did nothing.

The rescue attempt was poor. The dive master and another rescuer snorkelled to the area where the deceased was thought to be but were not weighted to enable them to submerge if necessary. When the victim was on the surface, they attempted to obtain positive buoyancy by trying to inflate her BCD instead of releasing her weight belt. In-water resuscitation attempts delayed getting the deceased onto the boat and a hard surface. Other relevant details in this case history are listed in Table 2.

The Coroner found that *'...the cause of death was salt-water drowning due to ascent barotrauma.'*

The postulated mechanism of death would be that the victim's asthma and pleural adhesions would have changed the compliance in areas of her lungs leading to ascent pulmonary barotrauma and cerebral arterial gas embolism (CAGE). Her bitten tongue would indicate a convulsion (hence CAGE).

Death 2

The deceased was a 58-year-old male, qualified diver, diving for crayfish.

Details of the dive are quoted from the Coroner's report.²

"The three of us entered the water, we were the last group to go into the water. The water was clear, with a little bit of current and about 6–8 metres of visibility. The object of the dive was crays. We were diving in about 9 metres of water...I checked our contents gauges...Jan and I had 100 bar left and Neville had 50 bar.

I motioned to Jan to stay where she was and motioned to Neville to ascend. He signalled back OK and we started ascending. I don't know if he was over-weighted or not but he wasn't going up very fast...I took hold of the front of his jacket to stop him coming up too fast if he decided to inflate his BCD vest. We surfaced about 40–50 feet south east of the boat. I asked him if he was OK and he said "Yes, fine". I told him to lay on his back and inflate his BCD and just fin back to the boat on his back, with his mouthpiece in. He said he was OK with that and I said I would go back down and get Jan and come back up to the boat. By the time I got down and got up with Jan, Neville was a bit further north of us. He was lying on his back and I thought he was hanging onto the mermaid line...I thought he was enjoying the sun. I got into the boat and took my gear off and called out to Neville but he didn't respond...I put my facemask back on and re-entered the water and swam over to Neville and grabbed hold of his vest and spoke to him but he didn't acknowledge me at all. I pulled him back to the boat, from about 30 feet from the stern. Whilst I was dragging him I noticed some vomit around his mouth. His mouthpiece wasn't in and his mask was in place and was clear. When I left him to go back for Jan his vest was about half inflated and when I returned to him from the boat it was fully inflated, it was almost drum tight. I can't understand why he had it so tight.

Dennis, Kate and Judith were in the water with Jan when I went back to get Neville...We manhandled him into the boat...After we got him on board I saw he wasn't breathing and checked his airway and saw it was clear and started CPR and mouth to mouth and Dennis grabbed the DAN oxygen kit. We couldn't get a pulse or any response. We had him on his side and he sounded like he was full of water. We did CPR and mouth to mouth for about 10 minutes and Kate said he was dead (she is a physiotherapist)."

COMMENTARY ON DEATH 2

Of note were his tight wetsuit, pleural adhesions, bitten tongue, enlarged heart and air found in the heart at post mortem and on chest X-ray (CXR). Relevant post-mortem findings and details are found in Tables 1 and 2. The deceased was diving in a group of three, did not ascend alone, but died on the surface alone.

The Coroner found that the deceased *"...died because he suffered a cerebral arterial gas embolism (CAGE) while ascending..."*

The postulated mechanism of death would be that the victim's pleural adhesions would have altered his pulmonary compliance, leading to pulmonary barotrauma and CAGE on ascent. A bitten tongue would indicate a convulsion and air noted in his heart at post mortem and in a CXR taken soon after death would indicate that a CAGE had occurred. In addition, if the convulsion had occurred while he was inflating his BCD, tonic hand contractions would have caused the BCD to over-inflate.

Death 3

The deceased was a 52-year-old, experienced, male diver, diving with a buddy on surface supply. A non-diver boatman who was a compressor attendant also subsequently died suddenly after attempting to resuscitate the deceased.

Details of the dive are quoted from the Coroner's report.²
"We both jumped in the water. We swam together the

Table 1. Post-mortem details of the five 'coroner' deaths

* 0.50 kg considered upper range of normal

Death	Sex	Age	Post-mortem findings
1	F	44	Adhesions right middle and lower lobes, pulmonary oedema, tongue bitten Weight – 83 kg (ideal 72 kg); Height – 177 cm
2	M	58	Adhesions upper lobe left lung, enlarged heart (0.655 kg),* enlarged left ventricle with thickened wall, tongue bitten, pulmonary oedema, air in right atrium and on CXR Weight – 113 kg (ideal 86 kg); Height – 186 cm
3	M	52	Heart enlarged (0.55 kg), ischaemic fibrosis, 60% occlusion of right and left main arteries, left lower lobe bullae bilaterally Weight – 132 kg (ideal 83 kg); Height – 183 cm
4	F	42	Food in larynx and bronchi, pulmonary oedema with bilateral pleural effusions, scars on abdomen and lumbar spine Weight – 104 kg (ideal 66 kg); Height – 171 cm
5	M	55	Enlarged heart (0.652 kg), hypertrophic left ventricle, air in right atrium and ventricle, mild interstitial fibrosis of myocardium, mild pulmonary oedema, CXR showed air in right atrium and ventricle, hyperinflated with oedema mainly in the apical areas, bitten tongue Weight – 127 kg (ideal 91 kg); Height – 191 cm

Table 2. Other relevant details of the five 'coroner' deaths

Death	BMI*	Relevant details
1	26 kg.m ⁻²	Frequent chest infections, Ventolin user, pneumothorax 1996, recent hospitalisation for laparoscopic appendectomy, two differing diving medical forms – one which had 'chest problems' ticked while the other not
2	32 kg.m ⁻²	Antihypertensive medication, left-sided chest injury in a motor vehicle accident – no CXR post accident, very tight wetsuit
3	38 kg.m ⁻²	Very tight wetsuit
4	35 kg.m ⁻²	Oesophageal reflux on medication, chronic back pain, on Panadeine forte, tight 7 mm wetsuit, overweighted with 18 kg of weight, unfit, cylinder out of test and unused for 12 months, BCD not maintained, inflator salt encrusted and stuck open when operated
5	35 kg.m ⁻²	Recent myocarditis, told not to dive by cardiologist, medications: Digoxin and Coversyl, tight wetsuit

* BMI = body mass index = weight (kg)/height² (m)

Range: 24–25 kg.m⁻² = normal; 25–30 kg.m⁻² = overweight; >30 kg.m⁻² = obese

whole time looking for crays...We had been down for about 15 minutes...We were in sight of each other the whole time. My ears started to hurt a little bit and I was getting a slight pain on the side of my temple...so I thought that it was time to go up, I signalled to Rex using my thumb indicating to go up and he signalled back with his thumb. We were down about 20–25 feet and were slowly ascending. Once at the surface we were swimming side by side back to the boat. We were about 10–12 feet from the boat. On getting to the side of the boat, I looked back and suddenly couldn't see Rex any more. I quickly looked around and then looked underwater and saw him on the seabed, he was lying on his back. He had both arms up in front of him with his palms up, there was no air coming out of his regulator and he wasn't moving at all. I still was getting air through my regulator and was not having any trouble breathing. I went and swam straight down to him and I could see that (his) face looked different. He is fairly well tanned and I noticed that even under water he looked pale and pinkish. I think his eyes were open. I grabbed him on the chest and shook him and there was no movement and I got no other response. I then unclipped his BCD vest and unbuckled his weight belt. I had to get his arms out of the harness and vest. This took a bit of time and was difficult. I just dropped all that gear and then I lifted him straight to the surface. At the side of the boat I got him half in and I got Paul to grab hold of him. I went around the ladder at the rear of the boat and hoisted myself in and Paul and me pulled Rex into the boat."

COMMENTARY ON DEATH 3

The victim was obese, with an enlarged heart and left lower lobe emphysematous bullae. He was wearing a tight wetsuit. The relevant post-mortem findings are in Table 1 and other details are listed in Table 2. Emphysematous bullae, obesity, a tight wetsuit and immersion would cause a decrease in functional residual capacity (FRC) causing hypoxaemia. The combination of hypoxaemia and sudden exercise (surface swimming) in someone with a hypertrophic left ventricle with 60% of the left main artery occluded would probably lead to arrhythmia, unconsciousness, drowning and death.

Death 4

The deceased was a 42-year-old, inexperienced, female diver. She was obese, unfit, on medication and diving with an equally inexperienced buddy. She was overweighted with 18 kg of weights. Relevant post-mortem findings are in Table 1 and other details are listed in Table 2.

Details of the dive are quoted from the Coroner's report.²

"...The conditions on that day as 'ideal', with calm water, a slight swell and clear skies...they swam out to Centre Rock, about 250 metres offshore, on the surface using their snorkels. They had a couple of rest stops on the way.

When they reached the area of the rock, and began diving, Ms C had trouble getting down because...she was 'too buoyant'. He put another weight on her belt. They began diving in only 3 to 4 metres of water.

After about ten minutes, Ms C indicated that she wanted a rest. They surfaced, and headed for some rocks so that they could climb out and rest. Mr R described what happened next:

What happened next is still somewhat blurry to me and seemed to happen all very quickly but probably occurred over several minutes. A wave caught us by surprise, it wasn't a large or exceptional wave but pushed us into the rocks, I saw Deb still had the regulator in her mouth at this time as she was forced under the water a couple times and appeared to be struggling for buoyancy.

The waves kept forcing us into the rocks and Deb was continually going under the water and I don't believe at this stage the regulator was in her mouth properly. Deb was still going under the water and I was attempting to pull her up, I struggled with her weight belt and was also trying to get some air back into her buoyancy vest but it did not appear to be going up, eventually I managed to get her weight belt off which helped increase her buoyancy. I was able now to keep her above the water and noticed her lips had gone blue. I took the regulator out of her mouth and started to give her mouth to mouth but was getting no response. I was yelling and screaming for help and someone must have heard me because a short time later a boat arrived to assist."

The Coroner's findings were *"...that the cause of Ms C's death was salt-water drowning. The major factors which caused this tragic outcome were Ms C's obesity, her lack of cardio-vascular fitness, her inappropriately heavy weight belt, and her inexperience which led her to become excessively fatigued. Added to that there were Ms C's health problems, including oesophageal reflux, and her back condition for which she was taking sedative medication."*

COMMENTARY ON DEATH 4

Of note here was the combination of surface difficulty, swallowing water and probable oesophageal reflux causing aspiration and laryngeal spasm. Food and vomit were found in the victim's trachea at post mortem. The pulmonary oedema found at post mortem may have been due to drowning, aspiration of gastric contents, a result of negative pressure breathing caused by laryngospasm or a combination of these factors.

Death 5

This is the death of a 55-year-old, experienced, male diver who had been warned by a cardiologist not to dive because of his cardiomyopathy and controlled cardiac failure. Relevant post-mortem findings are in Table 1 and other details are listed in Table 2.

Details of the dive are quoted from the Coroner's report.²

"...Bob had told me earlier this morning that he intended to dive for only 7 to 9 minutes due to his heart condition, it was a viral condition and his doctor advised he shouldn't dive.

When they reached the top of the anchor chain, about 1½ metres from the bottom Mr W swam up to Mr S and gave him a quick 'out of air' signal. He then removed the regulator from Mr S's mouth and began using it himself. Mr S then took Ms R's regulator from her mouth and began using it, and she then used her spare.

The three divers then commenced their ascent to the surface, connected in a 'daisy chain' via their regulators...Mr W was the first of the group above and behind Mr S, who was above and behind Ms R. Mr S was not able to maintain eye contact with Mr W during the ascent. He said: 'We then commenced our ascent up the anchor line. Bob was above me and Magdalena below me. We went up with a quick ascent rate...I couldn't see Bob as he was behind me, I wasn't looking for him, I just assumed he was on my reg. Once we had gone a few metres it felt like we were ascending at the same rate, in control. At about thirty metres, I'm not exactly sure of the depth but I believe we were about ten metres off the bottom, I noticed that my reg, the one that Bob had been on, was unattended by my left side. I believed that Bob mustn't have needed it any more and had let it go. I picked it up to use it myself and noticed that the mouthpiece was missing from the second stage. This was unusual and it made me anxious, I didn't understand it. I indicated to Magdalena to continue the ascent as rapidly as possible. By rapid I mean as fast as I could get up, I wanted to find out what Bob's situation was...We continued up the anchor line until we reached the gear line attached to it a couple of metres below the surface. At this time I let go of Magdalena's reg and continued up the last couple of metres on free ascent because it was quicker and I wanted to look for Bob.

On reaching the surface I could see two pairs of legs under the surface at the rear of the boat so I swam over there. I saw that Graham was supporting Bob's head out of the water, on seeing me he asked for help to get out of the water. I immediately dropped all my dive gear and finned over to the side into the boat. We got Bob's dive gear off and eventually got him into the boat with the use of ropes...we had to place ropes on various parts of his body to get him out of the water...I noticed whilst still in the water there was froth around Bob's mouth and nostrils and it wasn't moving. I don't think he was breathing. I checked for a carotid pulse but it was non existent."

The Coroner's findings were that *"...Mr W suffered a CAGE at some stage of his ascent leading to a convulsion, unconsciousness and drowning."*

COMMENTARY ON DEATH 5

The physiological effects of immersion, tight wetsuit and obesity in combination with a cardiomyopathic left ventricle are demonstrated here. Immersion centralised the victim's peripheral blood volume increasing his 'preload', which could not be accommodated by his cardiomyopathic left ventricle (Laplace's law). A decreased FRC due to immersion and a tight wetsuit plus the decreased chest wall compliance from the wetsuit and immersion added hypoxaemia to these cardiovascular effects. Dyspnoea due to left ventricular failure and hypoxaemia depleted his air supply, and rapid shallow breathing on ascent would have caused unequal alveolar emptying with the inevitable ascent pulmonary barotrauma and CAGE. Cardiac air was found at post mortem and on CXR taken soon after the death. In addition, the bitten tongue would indicate a convulsion.

Discussion

Various factors are common to all these deaths (Table 3). Obesity is associated with many medical problems. The incidence of mortality in overweight men is nearly four times greater than in those of normal weight. There is an increased rate of chronic diseases, many life threatening, including peripheral vascular disease, cardiorespiratory disease, liver disease, diabetes, polycythaemia, hyperlipoproteinaemia, hiatus hernia, oesophageal reflux and malignancies.⁵ Many of these conditions, particularly oesophageal reflux, hiatus hernia, cardiorespiratory disease and polycythaemia, are incompatible with 'safe' diving. The physiological effects of immersion may add further stress to the cardiorespiratory systems in obese subjects. Immersion increases the alveolar-arterial (A-a) oxygen gradient due to a decreased functional residual capacity (FRC), which is the result of a pressure differential between the abdomen and chest displacing the diaphragm into the chest thereby compressing the basal lung segments. Immersion also increases left ventricular work by centralising blood from the peripheral circulation.

All five cases would have been considered medically 'unfit' to dive by a majority of diving medical physicians. However, it is difficult to conduct a good risk assessment when the candidate is untruthful about his or her medical condition. Three had enlarged hearts and the physiological effects of immersion would have caused additional myocardial stress. Ventricular hypertrophy would have been evident on electrocardiography and CXR and would have led to additional cardiovascular testing (particularly stress testing and echocardiography). The pleural adhesions would have been evident on CXR, the bullae perhaps not.

None of these deaths was associated with equipment problems, although in deaths 3, 4 and 5 there were equipment issues to note. In death 3 the deceased had modified his weight belt by adding braces to it, which would have prevented it from being quickly released; this is contrary to safe diving practice.^{3,4} This had been done to

enable him to carry an excessive amount of weight, 20 kg, because of buoyancy problems related to his obesity. His BCD oral inflation valve was also malfunctioning. In death 4, the victim's buddy did have trouble with releasing the deceased's weight belt and inflating her BCD, which was later found to have a poorly functioning inflator. In death 5, one of the divers was lacking an 'octopus' regulator, which meant there was a 'daisy chain' effect when the deceased ran out of air.

All were diving with a buddy or buddies. Three were diving in a group of three. These deaths were associated with the dilemma of one being low on air whilst the other two were not and wanting to continue the dive. The 'correct' response is for all to ascend together; this did not occur in these cases.^{3,4}

Three were wearing tight wetsuits, which would compress veins and centralise peripheral blood volume, increasing preload and stressing both ventricles. A tight wetsuit would also decrease chest-wall compliance and would cause an upward displacement of the diaphragm into the chest compressing basal lung segments. The combination of an increased central blood volume, basal collapse and decreased chest-wall compliance would further decrease the FRC increasing the A-a gradient, which would compromise a person with decreased cardiovascular and pulmonary reserves.

These cases emphasise that, although salt-water drowning was described as the ultimate mechanism of death, a cause for the drowning must always be sought.

Table 3

Common factors in five divers' deaths in S. Australia

- All were medically 'unfit' to dive.
- Five had BMIs* in excess of 25 kg.m⁻², four in the obese range.
- Four had medical conditions associated with obesity (musculoskeletal problems, cardiac disease and poor physical fitness).
- Three had enlarged hearts.
- Three had pulmonary conditions incompatible with fitness to dive (bullae, pleural adhesions, asthma and a past history of pneumothorax).
- Three had bitten tongues, which would indicate a convulsion.
- All had pulmonary oedema and had suffered from salt-water drowning.
- All were diving with a buddy.
- No faulty equipment could be implicated in the deaths.
- Three had tight wetsuits, which would have compromised their cardiorespiratory reserve.

* BMI = body mass index = weight (kg)/height² (m)
Range: 24–25 kg.m⁻² = normal; 25–30 kg.m⁻² = overweight;
>30 kg.m⁻² = obese

South Australian Coroner's recommendations²

The general recommendations from the SA Coroner are reproduced here.

"Pursuant to that Section, I make the following recommendations:

1. *All persons engaged in recreational underwater diving should undergo an examination by a registered general medical practitioner trained in hyperbaric medicine on a regular basis, preferably annually but not less frequently than every two years.*
2. *Medical practitioners should decline to conduct such examinations unless they are appropriately qualified to do so.*
3. *Medical practitioners conducting such examinations should, if they are not the subject's regular medical practitioner, require the subject to produce a referral letter detailing the subject's medical history as far as it is known.*
4. *Medical practitioners conducting such examinations should warn the subject that diving is a potentially lethal activity if undertaken by a person with certain medical conditions, and that absolute honesty in providing background medical history is called for.*
5. *If there is any doubt about the subject's health, the medical practitioner should arrange such follow-up tests as chest X-rays, hypertonic saline tests, or whatever else may be indicated, before passing the subject as fit to dive. Any doubt should be resolved against passing the subject as fit, until such follow-up tests demonstrate fitness to dive.*
6. *The recreational diving industry should conduct an awareness campaign among its member organisations and the diving public about the dangers of diving with certain medical conditions, the need for regular medical examinations at least every two years, the need for absolute honesty during such examinations, and the responsibility a diver has both personally and to his or her diving colleagues to ensure that he or she is fit to dive."*

Comments on the Coroner's recommendations

Diving medical examinations performed only by medical practitioners trained in diving medicine have at last been recommended. Referral letters with medical information, if the diver's regular medical practitioner is not performing the examination, would eliminate much of the inaccurate medical information prompted by other interested parties and omission or concealment by the diver of conditions they know about.

Some may consider the suggestion of a medical every two years excessive but this could be replaced by a self-assessment every two years, with notification to a medical referee if there has been a change in the diver's medical

health in the interim. This would be in line with the current practice for employed divers in New Zealand.⁶

The Coroner also recognises that divers have a 'duty of care' to each other and should take responsibility for their actions.

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The Maldives

Theme: Evolving Diving Practices

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