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Hypertension Screening of Commercial Divers from an Occupational Medicine Perspective

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Hypertension Screening of Commercial Divers from an Occupational Medicine Perspective

by

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Capstone

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Dedication

This thesis is dedicated to Giugi Carminati, whose dedication and support has enabled me to follow the career of my dreams;

The Neutral Buoyancy Laboratory personnel, who work ceaselessly, outside the limelight to provide astronauts with the most realistic training environment on Earth;

And NBL Medical Team and their Medical Director, Bob Sanders, who took me under their wing and brought me into the tight-knit family that works behind the scenes to ensure the safety of all the NBL team.

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Hypertension Screening of Commercial Divers from an Occupational Medicine Perspective

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Hypertension is one of the most common chronic diseases in the world: in the US, it affects one third of the adult population. Most cases are primary hypertension - with no identified cause - and significantly increase the risk for cardiovascular disease and stroke. At NASA's Neutral Buoyancy Laboratory (NBL), there is a cadre of professional divers who provide underwater support during extravehicular activity training (EVAs, commonly referred to as 'Spacewalks') for astronauts. The NBL occupational health program requires regular "work-site" physical exams, including blood pressure checks, on at least a weekly basis. Although some blood pressures measured during such regular checks were elevated, the diagnosis and management of blood pressure was outside the scope of that occupational medicine program. As a result, there was no protocol to analyze and manage asymptomatic elevated blood pressure if and when it warranted physician follow up. We therefore analyzed the blood pressure data from all divers in 2015, vetted the worksite physical and developed a referral pathway to ensure divers have access to effective management of their blood pressure while minimizing impact of such a program on daily operations.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

ACE	Angiotensin Converting Enzyme
ARB	Aldosterone Receptor Blocker
CCB	Calcium Channel Blocker
DBP	Diastolic Blood Pressure
EMR	Electronic Medical Record
EVA	Extra Vehicular Activity
HCTZ	Hydrochlorothiazide
HTN	Hypertension
JNC	Joint National Committee
NASA	National Aeronautics and Space Administration
NBL	Neutral Buoyancy Laboratory
SBP	Systolic Blood Pressure

INTRODUCTION

Hypertension is one of the most common chronic diseases in the world: in the US, it affects one third of the adult population (1). Most cases are primary hypertension – with no identified cause – and significantly increase the risk for cardiovascular disease and stroke. At NASA's Neutral Buoyancy Laboratory (NBL), a cadre of professional divers provides underwater support during extravehicular activity training (EVAs, also commonly referred to as 'Spacewalks') for astronauts. The NBL occupational health program requires regular "work-site" pre-dive physical exams, including blood pressure checks, at least weekly. Although some blood pressures (BP) were elevated, the diagnosis and management of blood pressure was outside the scope of this occupational medicine program; prior to this review, there was no established follow up mechanism to address elevated blood pressure if and when it was detected.

High blood pressure, or hypertension (HTN), is one of the most common chronic conditions, affecting approximately 30% of the adult US population (1), and over two-thirds of people 75 years old or older (CDC). Even with this prevalence, only half the people who suffer from high blood pressure know their blood pressure is high (2).

Chronic hypertension leads to coronary heart disease, stroke, nephropathy, retinopathy and heart failure (3). The Eighth Joint National Committee (JNC 8) defines hypertension as a systolic blood pressure (SBP) above 140 mmHg, and/or a diastolic blood pressure (DBP) above 90 mmHg (150/90 for individuals over 60 years old) (4). Some studies suggest complications increase when BP is above a threshold as low as 115/75, and thus lower blood pressure targets and definitions have been proposed. However, that data are not consistent, and JNC 8 recommends that an intervention should begin with a blood pressure over 140/90 (150/90 for individuals over 60 years old) (4). In this paper we will use >140/90 to mean either systolic and/or diastolic blood pressure over the respective numbers, although only one of the two blood pressures may cross the threshold.

Once HTN is identified, it should be treated to a target BP of <140/90. When treated, there is no difference in risk between individuals with SBP <120 and 120-139 (Hazard ratio 1.0, 0.85-1.17) but those with SBP >140 had a 46% increase in risk of an event (Hazard ratio 1.46, 1.26-1.69) (5).

As hypertension continues to be a leading chronic medical disease, with severe complications (stroke, heart failure, kidney failure), early diagnosis and intervention is a critical component of public health programs. Furthermore, cardiac events remain the second leading cause of death in divers, secondary only to drowning (6). Treatment is widely available and effective, but it is critical that people get screened. Even still, half of people with hypertension do not know they suffer from it in spite of current outreach, information and screening programs (2).

The Sonny Carter Training Facility in Houston, Texas, houses NASA's Neutral Buoyancy Laboratory (NBL). The primary purpose of the NBL is to allow astronauts to train for EVAs. In addition it provides an environment to develop and practice space-capsule water operations, as well as provide physiologic training with on-site altitude and hyperbaric chambers. Divers are used to provide in-water astronaut assistance during the practice EVAs, videography of practice runs, and reconfiguration of the mock-ups for the training mission required. As part of their employment, all divers must undergo annual physicals in the NASA clinic as well as weekly physical checks.

Occupational medicine programs focus on ensuring the capability and safety of their workforce. Although these programs are not tasked with diagnosing and managing blood pressure, the blood pressure checks present an opportunity to inform the employee of their numbers, the risks of high blood pressure, and direct them to resources that help reduce their blood pressure such as information handouts, brochures, and referral to a primary care clinic, as well as counseling with a nurse specialized in blood pressure interventions.

The specific aims of this study are to validate the practice of work-site BP checks, ensure reliability of the results obtained at the NBL, and to develop a worksite hypertension protocol that refers divers at the NASA Neutral Buoyancy Laboratory to the clinic's hypertension education program.

METHODS

The electronic medical record (EMR) was queried for all diver physicals performed in 2015. These are required for anyone diving in the pool, and includes both divers who work at the NBL (Staff Divers) as well as other divers such as suit engineers, test personnel, members of the media, flight surgeons, management employees, and others (collectively, Guest Divers). Ninety individuals were identified, Astronauts were not included in either group.

We collected the age, gender distribution, pre-existing diagnosis of hypertension (HTN), pre-hypertension (PRE), and also antihypertensives used by each individual, which in our population was angiotensin-converting enzyme inhibitors (ACE inhibitors), aldosterone receptor blockers (ARBs), calcium channel blockers (CCBs) and hydrochlorothiazide (HCTZ). Blood pressure measurements were from both the occupational medicine clinic and the worksite.

T-tests were used to compare blood pressure and Fisher's exact test for categorical variables. Paired t-tests were used to compare a diver's work-site blood pressures against their clinic blood pressure. Various techniques were used to prioritize divers needing referral and in conjunction with meetings with clinic staff a referral algorithm was developed.

RESULTS

Ninety divers were identified as qualified for diving in 2015, of which sixty-four were staff divers (employees) and twenty six were guest divers. Ten individuals never dove, and thus did not have a work-site blood pressure, but are included in the analysis since they were listed on the diving roster as medically fit to dive if needed. Fourteen female divers were identified. Ten divers with “pre-hypertension”, one with white coat hypertension, and one with “elevated blood pressure without hypertension” were classified as “Pre-hypertension”. Ten divers were identified as taking medication for hypertension. One diver was identified as taking an antihypertensive, but did not carry the diagnosis of hypertension – that diver was not retroactively reclassified as hypertensive. (See Table 1).

Total Divers	N= 90
- Male/Female	76/14
- Age – mean (range)	41.3 (20-63)
- Age - male	42.1 (20-63)
- Age - female	36.8 (24-53)
Diagnosis	
- Hypertension	11 (12.2%)
- Pre-hypertension	12 (13.3%)
Medication	
Total	10
- Amlodipine	2
- Lisinopril	3
- Lisinopril-HCTZ	2
- Verapamil	1
- Valsartan-HCTZ	2
Status	
- NBL Diver	64 (71.1%)
- Guest Diver	26 (28.9%)

TABLE 1 – Description of study group

One of the most critical questions in our study was the usefulness of the work-site blood pressure measurements. Divers require a focused physical to screen for any cardiopulmonary and ENT pathology. A set of vitals is collected with the physical, which yields a blood pressure measurement that is not taken strictly per JNC 7 guidelines (7). Significantly altering the routine physical exam at the work-site went against our 'minimal impact' approach, so understanding the relationship between the work-site and the clinic blood pressure measurement was critical. This is illustrated in Figure 1A, which depicts each individuals' average clinic measurement (Y axis) and work-site measurement (X-axis). This allowed us to visualize the relationship between the two measures at the individual level, to confirm there did not appear to be any obvious bias or systemic errors that would not be readily apparent in a statistical test. We performed a pair-wise comparison of work-site blood pressures against clinic values, demonstrating that the two were in good agreement (Figure 1B), with the DBP measurements at the work-site being approximately 5 mmHg lower than in the clinic. This is sufficiently similar that we could use work-site blood pressures directly, without having to modify procedures at the NBL or having to perform a mathematical transform.

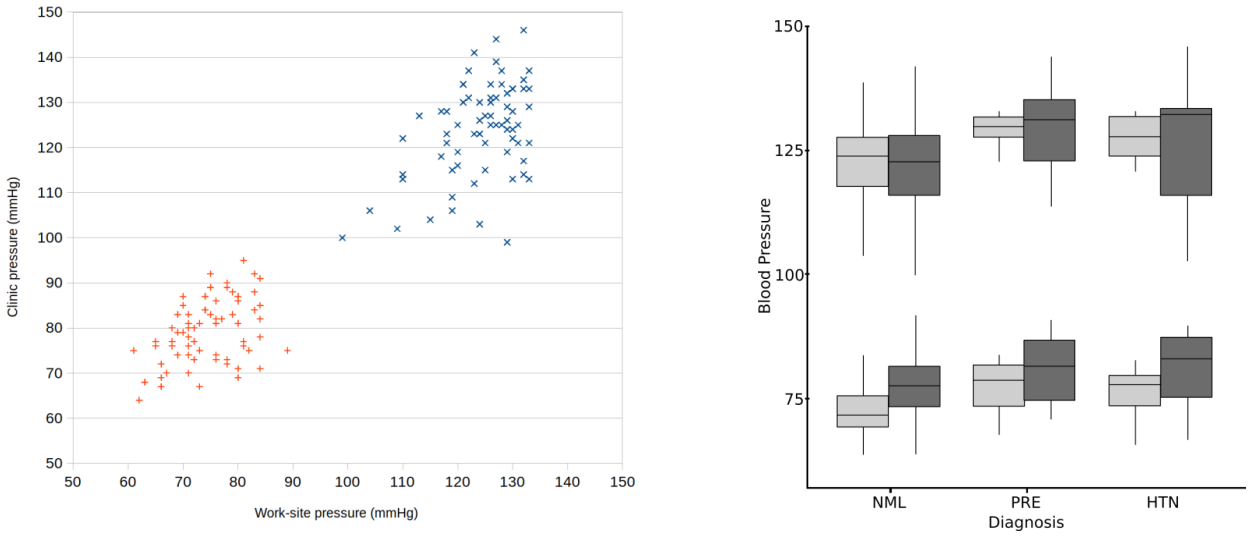


FIGURE 1 – A) Comparison of Clinic vs NBL blood pressure measurements; B) Boxplot showing distribution between blood pressures from the NBL (light) and clinic (dark) stratified by diagnosis of hypertension (HTN), prehypertension (PRE) and no diagnosis (NML). Pairwise comparison of work-site against clinic blood pressure. SBP: Systolic Blood Pressure, $p=0.854$ (mean difference 0.21, 95% CI (-2.07, 2.49)); DBP: Diastolic Blood Pressure, $p<0.001$ (mean difference -4.69, 95% CI (-6.38, -3.00)).

With the ability to rely directly on blood pressure measurements from the work-site, we assessed various ways to identify divers who were undiagnosed with hypertension. Our goal was to develop a set of conditions that would trigger referral for blood pressure counseling. To minimize delay to referral for "at-risk" divers, we have demonstrated that the work-site physical is sufficient. The criteria need to be straightforward and simple to implement and minimize disruption to the patient flow so as not to delay operations. We initially considered using average SBP at the work-site, since this does not affect operations, but this method requires a regular run through the list of divers in the electronic medical record to check the latest blood pressures. It would also mean that if someone develops hypertension, it would take many elevated blood pressures to pull the average above 140/90. When we analyzed the data, we noted only one individual would be identified this way using work-site blood pressures – and only three additional patients would be identified through the clinic. Though it would likely be very specific, this method introduced too much delay to referral and suffers from poor sensitivity early on.

Ultimately, we developed a new algorithm for diagnosing and referring divers with hypertension, using the total number of elevated blood pressures. This new approach consists of noting how many times in a given year an individual has a work-site SBP above 140 mmHg or a DBP above 90 mmHg (referred to as a blood pressure ">140/90"). This record is initiated by the medical technicians and physicians who measure blood pressures at the work-site, then circle the elevated blood pressure on the physical exam forms turned in by the divers. The forms are transcribed into the EMR and each elevated blood pressure counts as a 'strike.' When a diver acquires three elevated blood pressure measurements in a 12-month period, they are referred for elevated blood pressure education at the on-site clinic. If this is their first-time diagnosis of hypertension and they had three elevated measurements, they are referred to the clinic for 24-hour blood pressure monitorring. We use this system to to control for "white coat syndrome" (performance anxiety) versus true hypertension. For those that demonstrate chronic elevation over a 24-hour period, they will be referred for education and management. This approach minimizes overhead and does not disrupt the flow of divers prior to the start of operations. Furthermore, since prior diagnosis of hypertension is not considered, this method also serves to

refer divers with hypertension that may require additional intervention to control their blood pressure.

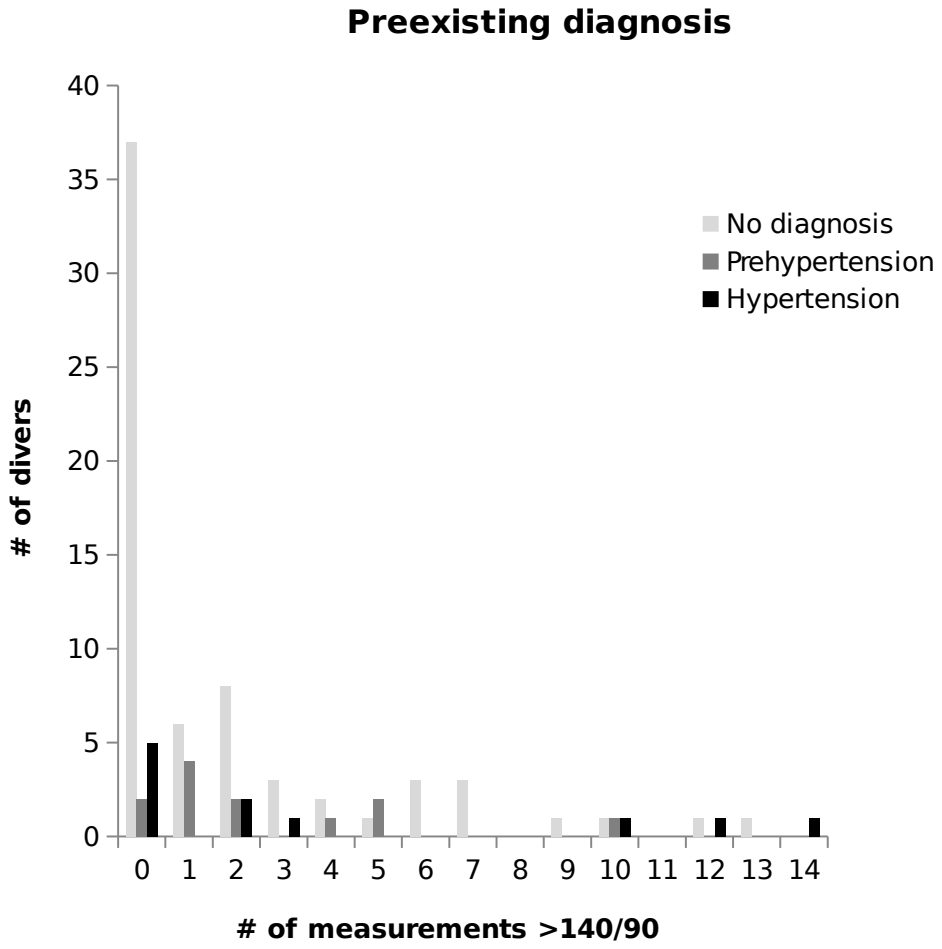


FIGURE 2 - Divers with work-site SBP > 140mmHg or DBP > 90mmHg

Using this method we identified sixteen divers who were unaware of their persistently elevated blood pressure. We were also able to differentiate between seven divers with hypertension who appear to have well-controlled blood pressure and four who would benefit from further management for persistently elevated blood pressure. In addition, we identified four out of twelve divers previously diagnosed with pre-hypertension who met criteria for referral (Figure 2).

In total, our population of ninety divers had diagnosed rates of hypertension of 12.2% (11/90). Using our criteria of three "allowed elevated blood pressures," we identified that 26.7% (24/90) of divers would benefit from intervention. If all sixteen previously undiagnosed divers are diagnosed with hypertension, this would yield a total prevalence of 30.0% (27/90), closely matching the 29.0% prevalence in the US adult population (8). It also highlights that as many as 16 of 27 divers with hypertension are unaware of their condition, as reported in other studies (2).

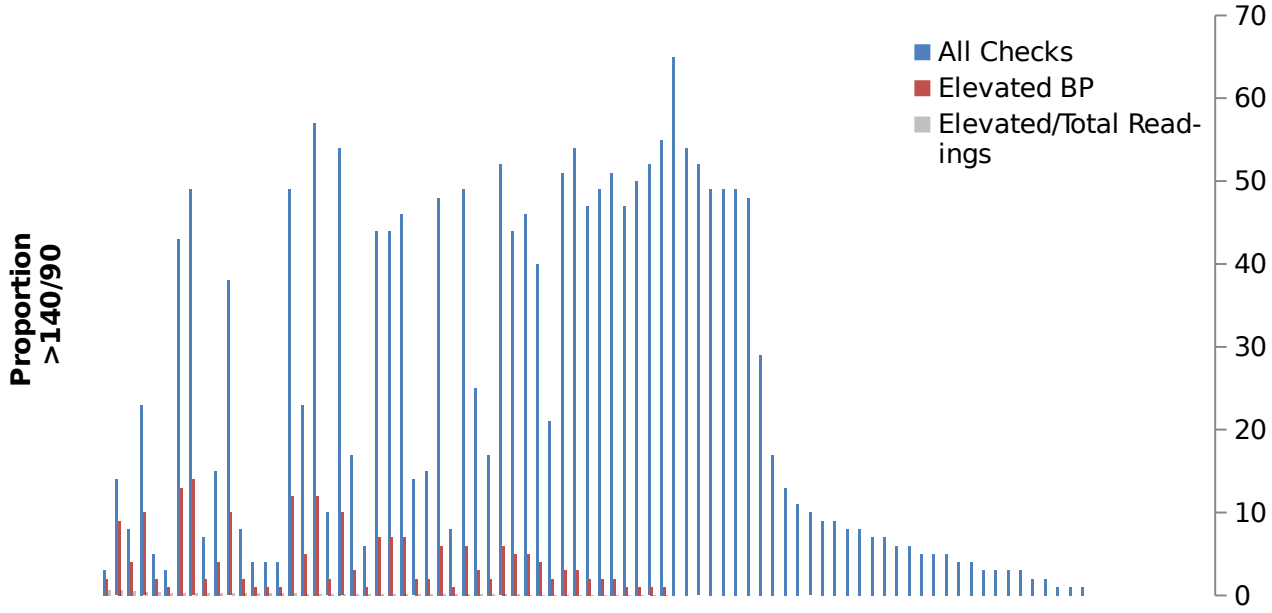


FIGURE 3 – Distribution of normal and elevated blood pressure readings per diver (NBL readings only), ordered by decreasing proportion of elevated blood pressure readings.

Although our population had many individuals that exceeded the 140/90 threshold at some point, the divers were being measured repeatedly, so we also looked at how often their blood pressure exceeded 140/90 (Figure 3). We also compared how often they had elevated blood pressures to their average blood pressure using all combined measurements.

Finally, we addressed a concern that the staff divers exhibit a significant difference in prevalence of hypertension when compared to the guest divers. Currently both groups are held to the same blood pressure standards and have similar work-site physicals. We compared both groups in terms of the prevalence of hypertension as well as pre-hypertension and found no statistically significant difference. (Figure 4).

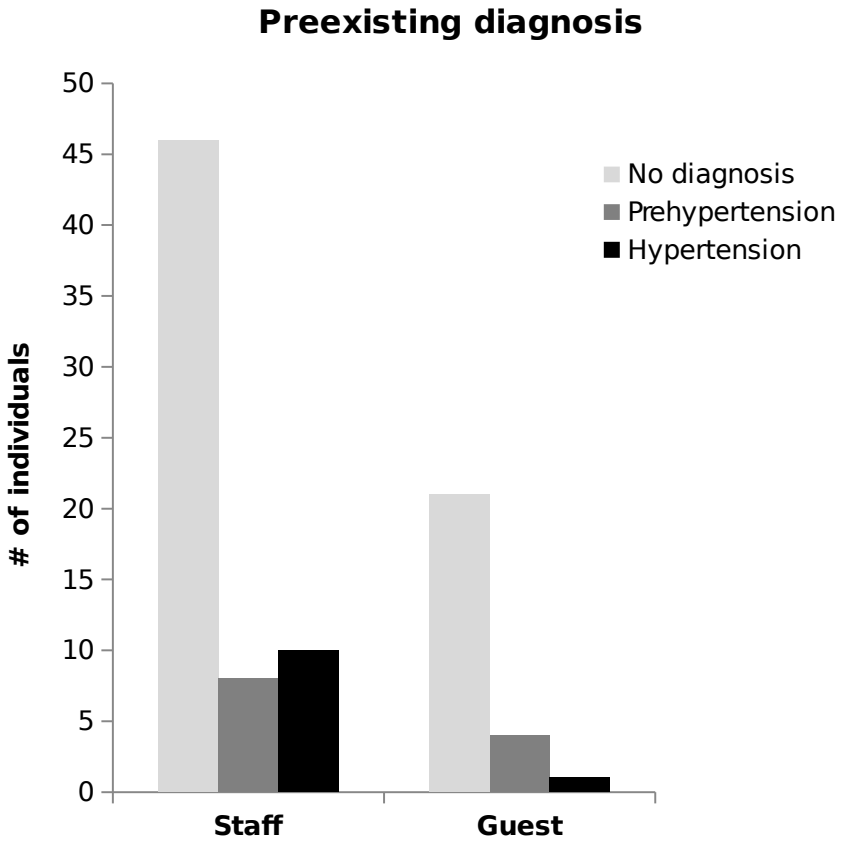


FIGURE 4 – Diagnosis by diver class – guest vs staff divers; *p=0.501 (Fisher's Exact Test)*

DISCUSSION

The prevalence of diagnosed hypertension in our diver population was low (12.2%) compared to the expected US adult population average (29%), but we initially assumed a "healthy worker" bias. After applying our criteria, we found an additional 17.7% who could be diagnosed as hypertensive. Interestingly, this matches the expected 29% overall prevalence, and approximates the 50% split in 'known' versus 'unknown' hypertension in the average population at large. The similarity of blood pressures between the work-site and the clinic was also surprising. JNC 7 recommends that blood pressure be measured after sitting in a quiet room for 5 minutes, averaging two measurements and with no recent exercise (7). When divers visit the clinic, this protocol is feasible, but it is not feasible at the work-site when everyone is gearing up for operations. We expected higher SBPs at work than in the clinic; fortunately this was not the case (Figure 1). As a result, systolic blood pressure can be used directly from work-site physicals without a correction or mapping function. Interestingly, the DBPs were slightly lower at the work-site. This may be a result of automated blood pressure cuffs used in the clinic versus manual measurements taken at the work-site. Either way, this approach appears robust enough that other occupational medicine programs could consider using this same approach. The EMR review was also revealing in that the divers were using a variety of different anti-hypertensive medications. Hypertension is managed by the individual's primary care provider and their choice of pharmaceutical agent. Beta blockers are outright disqualifying for commercial diving (9) due to the perceived inability to mount a tachycardic response. ACE inhibitors & ARBs are preferred in the diving community, but only three of the ten medicated divers were on an ACE inhibitor and another four were on ACE/ARB with hydrochlorothiazide.

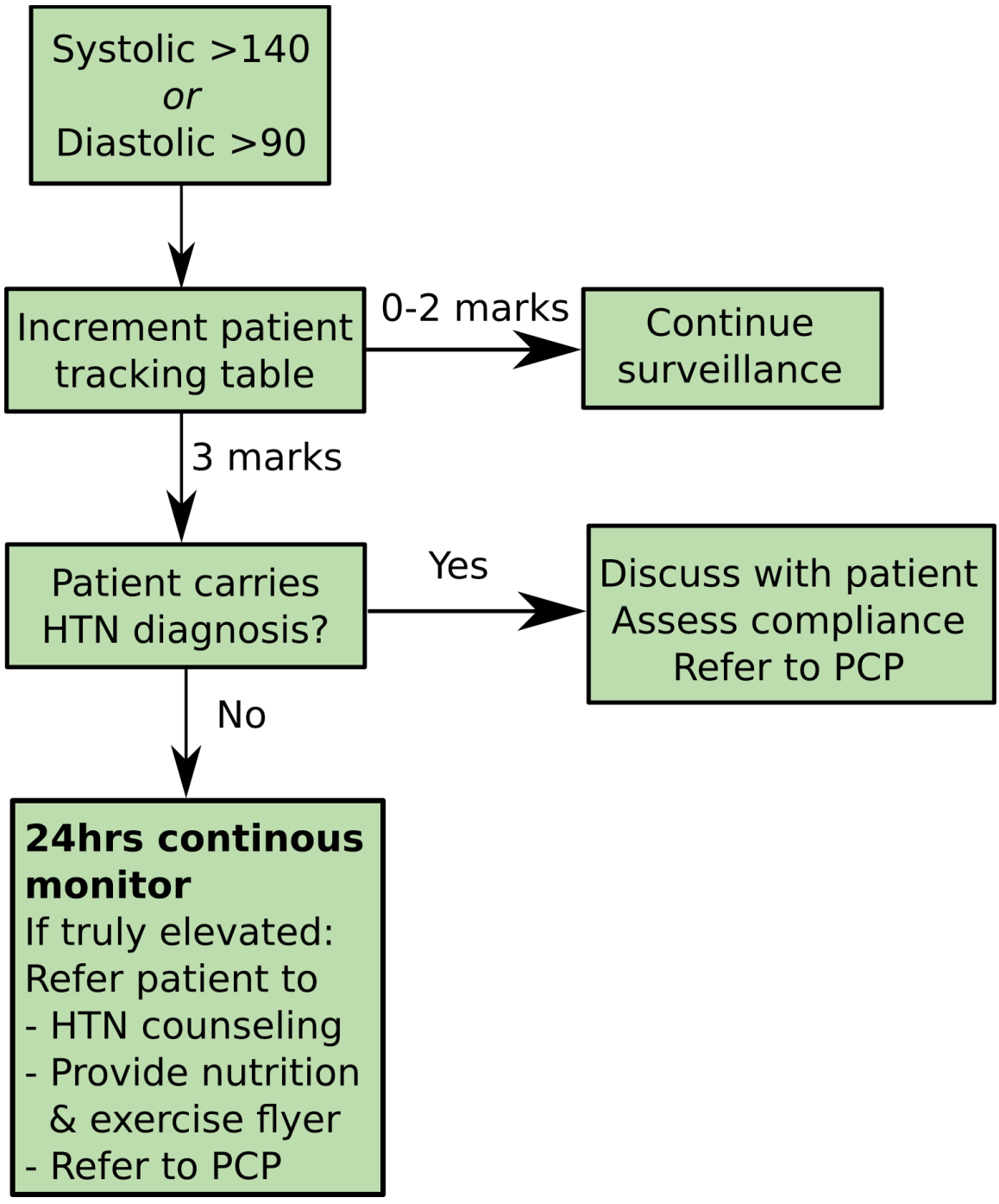
Using three elevated blood pressures to trigger referral minimizes overhead and has the added benefit of identifying divers with poorly controlled hypertension. It also made it easy to explain and implement since this technique does not require calculations of moving-window averages or repeated EMR queries. Instead, a simple table that lists medical record numbers and number of elevated blood pressures is sufficient.

The sensitivity is easily adjusted by modifying the number of 'strikes'. After a year of implementation, we can review blood pressures and total number of referrals, and either increase or decrease the number of elevated blood pressures required for referral with minimal overhead. This method also did not appear to be overly skewed towards detecting individuals already diagnosed.

We hope that our experience can serve as a guide to other occupational medicine programs. For those seeking to gain additional meaningful use of their EMR, this process can be readily implemented. Detailed analysis can identify further areas for improvement: for example, in the choice of pharmacologic agents. We can easily identify all divers on medications, as well as those we are referring for initial management, so as to encourage the divers to discuss their medication with their provider while considering the particular physiology of their line of work.

This study does not address the risk of starting a diver on blood pressure medications. We use the JNC guidelines that set a systolic of >140 or diastolic >90 as the threshold to diagnose hypertension and initiate therapy. Our approach does not include pre-hypertensives (SBP 120-140; DBP 80-90) for referral. Some studies suggest benefit from initiating pharmacologic treatment at lower blood pressures. However, there is a paucity of data on SCUBA divers. Although we had many divers that had at least three blood pressures >140/90, most had an average blood pressure below that (Figure 3). The exposure to increased ambient pressure, immersion, and other effects may result in a different side effect profile from various anti-hypertensives that may ultimately indicate that divers may benefit from pharmacological treatment at a different blood pressure threshold. So far there is expert opinion that recommends against certain medications because they may have worsened side effects (for example, dehydration due to diuretics may predispose someone to decompression illness or worsened motion sickness). A prospective study that could randomize divers to different anti-hypertensives and assess for benefits and adverse events would be required. Our approach is flexible enough that in the future, we could adjust the threshold to referral (which includes diet and exercise interventions) to include pre-hypertensives.

Appendix A Screening Algorithm



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Vita

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He attended the International School of Geneva, Switzerland, and then completed a Bachelor of Science in Physics at the University of Houston Honors College in Houston, Texas.

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