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Abstract: The impact of COVID-19 pandemic on the cardiovascular healthcare services in Croatia has not been systematically examined. In this study, we compared utilization and provision of cardiovascular services in Croatia during the pre-pandemic period (2017 to end of 2019) and pandemic period (2020 to end of 2021) by using large nationwide data from the Croatian Health Insurance Fund, an institution covering 95% of all insurance claims in Croatia. We report that the use of advanced heart failure treatment modalities increased while the number of coronary angiographies decreased while the number of performed percutaneous coronary interventions remained similar, even increasing in the setting of acute myocardial infarction, comparing pandemic to pre-pandemic period. Similarly, the number of transcatheter aortic valve implantations increased significantly during the pandemic era. There was a significant increase in laboratory diagnostic testing with troponin and natriuretic peptide assays during the pandemic period while the use of most cardiovascular services remained stable or only slightly decreased, compared to pre-pandemic period. These data suggest that Croatian cardiovascular healthcare services during COVID-19 pandemic showed resilience and managed to maintain or even increase the number of various diagnostic and interventional procedures despite the widespread societal and logistical challenges encountered during pandemic.

Keywords: cardiology services; Croatia; COVID-19; pandemic; healthcare; national sample; interventional cardiology; hospitals; admissions; outpatient

1. Introduction

The coronavirus disease (COVID-19) pandemic has been declared by the World Health Organization (WHO) on March 11th, 2020. That was preceded by a forewarning from the same institution on January 30th, 2020 [1]. From 571 cases of COVID-19 observed on January 22, 2020, in China only one month later, on February 16, the number of COVID-19 cases reached 51,857 cases globally in 25 countries [2]. Overall, we can realize that at the beginning of 2020 the coronavirus pandemic started.

As number of COVID-19 cases have been increasing, number of epidemiological interventions were introduced worldwide, and patients concerns and fear of hospital visiting increased. It resulted in sharp decrease in number of non-Covid hospital appointments, admissions, and medical procedures. The analysis from 201 hospitals in 36 states across USA of approximately one million medical admissions, revealed substantial decline in non-COVID-19 admissions from February to April 2020, exceeding 20% but later had rebounded to 16% below the pre-pandemic level [3]. In the multicentre European observational registry from fifteen centres in 12 countries 54,331 patients were analyzed and acute admissions to emergency departments in 2020 decreased by incidence rate ratio (IRR) 0.66 compared to 2019 [4].

The COVID-19 epidemic influence on non-COVID-19 cases were also recorded in Republic of Croatia. An analysis of the hospital admission rate in Croatia showed a 21% decrease in the total number of admissions across the Croatian hospitals during 2020. The decrease in the hospital admissions were noticed in some non-elective Diagnosis Related Groups (DRG classes) such as class

of cancer, stroke, major chest procedures, heart failure, and renal failure. In the same study the decrease in the number of CVD admissions in Croatia was 26% [5].

As the prevalence of cardiovascular diseases (CVD) is high worldwide, for example in USA the overall prevalence in adults ≥20 years of age is 49.2% and increases with age in both males and females [6], we can expect huge impact of Covid-19 pandemic on CVD prevention, diagnostics, and treatment. Cardiovascular diseases are also the main causes of deaths in Croatia and ischemic heart disease represents one fifth of all deaths [7]. It is expected that delay of cardiovascular health care delivery during COVID 19 pandemic would negatively affect cardiovascular outcomes of non-Covid cardiovascular patients in the future. So far, the impact of COVID 19 pandemic on cardiovascular healthcare delivery in Croatia has not been comprehensively analyzed at national level.

Therefore, the aim of the present study was to analyze the impact of Corona virus pandemics on hospital admissions and quantify the magnitude of change of related cardiology procedures in Croatia.

2. Materials and Methods

Data for the study were publicly available upon the request from the Croatian Health Insurance Fund (CHIF). According to the last 2021 census, Croatia has about 3.800,000 citizens and CHIF covers health services for over 95% of population. According to World Bank, Croatia is a country that is defined as a high-income country (group of nations with a gross national income per capita of US$13,589 or more in 2022). The data from all Croatian non-specialized acute hospitals, 11 tertiary level hospitals and 22 secondary level hospitals were included in the present study and they account for 96% of the Croatian inpatient activity.

The CHIF dataset comprised of inpatient data grouped in accordance with Australian Refined Diagnosis Related Groups (AR-DRGs), a data stratification system that is based on the Australian DRG system. It utilizes a combination of the ICD-10AM and ICD-10 classifications for the coding of diagnosis, and Australian Classifications of Health Interventions (ACHI) for the coding of procedures. The DRG grouping algorithm is based on AR-DRG version 5.2 which assigns cases to 671 DRG classes.

We collected and included data for the period from January 1, 2017, to December 31, 2021. The pre-pandemic period was defined as period between January 1, 2017, and December 31, 2019 and mean of those three years were calculated. Pandemic period was defined as period between January 1, 2020, and December 31, 2021 and mean of those two years were calculated. To compare the incidence rates of events occurring at those two periods, incidence rate ratio (IRR) as relative difference measure was used.

Statistical analysis

For the principal statistical analysis, we used an "Odds Ratio" calculator. The odds ratio (OR), its standard error and 95% confidence interval are calculated according to Altman, 1991. A standard normal deviation (z-value) is calculated as ln(OR)/SE{ln(OR)}, and the P-value is the area of the normal distribution that falls outside ±z. The Odds Ratio calculator is available at https://www.medcalc.org/calc/odds_ratio.php

3. Results

During the pandemic period hospital admissions of heart failure patients in Croatia decreased significantly from 6021 per year in the pre-pandemic period to 5474 per year in the pandemic period by IRR 0.909 (95% CI: 0.876 – 0.943; p<0.0001). Conventional diagnostic methods performed in hospitals for HF patients, such as echocardiography decreased even more, from 55,003 per year in the pre-pandemic period to 46,880 per year in the pandemic period by IRR 0.852 (95% CI: 0.842 - 0.863; <0.0001). On the other hand, biochemical tests in HF patients such as natriuretic peptides tests increased sharply, from 19,830 per year in the pre-pandemic period to 42,787 per year in pandemic period by IRR 2.158 (95% CI: 2.122 - 2.194; p<0.0001). Advanced therapeutic methods in HF patients

previously well-established in Croatia as the heart transplant, and device therapies such as cardiac resynchronization therapy (CRT) implantation and ventricular assist device (LVAD and RVAD) implantations weren't affected during the COVID-19 pandemic period and non-significant increase during pandemic period was observed. As expected, significant increase in extracorporeal membrane oxygenation (ECMO) procedures during pandemic period were recorded (IRR 1.355 (95% CI: 1.140 – 1.611; p<0.0004), as shown in Table 1.

Table 1. Incidence rate ratios and utilization of heart failure-related healthcare services during pre-pandemic and pandemic period.

Variable	Pre-pandemic N per year (2017 to 2019)	Pandemic N per year (2020 to 2012)	IRR (95% CI)	P-value
HF admissions	6,021	5,474	**0.909** (0.876 – 0.943)	**<0.0001**
CRT implantations	162	200	1.228 (0.993 – 1.521)	0.0510
VAD implantations	27	25	0.926 (0.515 – 1.657)	0.784
ECMO uses	234	317	**1.355** (1.140 – 1.611)	**0.0004**
Heart transplants	32	36	1.094 (0.658 – 1.825)	0.7162

Abbreviations: CRT-cardiac resynchronization therapy; ECMO-extracorporeal membranous oxygenation; HF-heart failure; VAD-ventricular assist device.

During the pandemic period hospital admissions of acute coronary syndrome (ACS) patients in Croatia decreased significantly, from 11,481 per year in the pre-pandemic period to 10,275 per year in the pandemic period by IRR 0.895 (95% CI: 0.871 - 0.919; p<0.0001).

Regarding to subgroups of ACS patients, number of unstable angina (UA) patients decreased significantly from 1,910 per year in the pre-pandemic period to 1,525 per year in the pandemic period by IRR 0.798 (95% CI: 0.746 – 0.854; p<0.0001), but the number of admitted NSTEMI patient per year was similar in the pre-pandemic and pandemic period (5,330 vs 5,107 per year; p=0.1303), while the number of STEMI patients decreased significantly from 4,311 per year in the pre-pandemic period to 3,658 per year in the pandemic period by IRR 0.845 (95% CI: 0.808 - 0.883; p<0.0001).

As expected, hospital admissions for the chronic coronary syndrome (CCS) patients decreased the most, from 6,270 per year in the pre-pandemic period to 4,122 per year in the pandemic period by IRR of 0.657 as shown in Table 2.

Table 2. Incidence rate ratios and number of ACS- and CCS-related hospitalizations during pre-pandemic and pandemic period.

Variable	Pre-pandemic N per year (2017 to 2019)	Pandemic N per year (2020 to 2012)	IRR (95% CI)	P-value
ACS, overall	11,481	10,275	**0.895** (0.871 – 0.919)	**<0.0001**
STEMI	4,311	3,658	**0.845** (0.808 – 0.883)	**<0.0001**
NSTEMI	5,261	5,107	0.971 (0.934 – 1.009)	0.1303
Unstable angina	1,910	1,525	**0.798** (0.746 – 0.854)	**<0.0001**
CCS	6,270	4,122	**0.657** (0.632 – 0.684)	**<0.0001**

Abbreviations: ACS-acute coronary syndrome; CCS-chronic coronary syndrome; STEMI-ST elevation myocardial infarction; NSTEMI-non-ST-segment elevation myocardial infarction.

As shown in Table 3, a total number of coronary angiographies (CAG) in Croatia decreased significantly in pandemic period, from 25,938 per year to 20,134 per year (IRR 0.776 (0.762 - 0.791); p<0.0001). On the other hand, the total number of PCIs remained similar in both periods (IRR 0.985 (0.956 - 1.015); p=0.3402). Despite of significant decrease in the number of admitted ACS patients in the pandemic period as mentioned above, the number of PCIs in the settings of acute myocardial infarction increased significantly, from 4,214 per year in the pre-pandemic period to 4,424 per year in the pandemic period by IRR 1.050 (95% CI: 1.006 - 1.095; p<0.0238). On the other hand, CAG in the settings of acute myocardial infarction but without performed PCI decreased significantly in the pandemic period by IRR 0.836 (95% CI: 0.769 - 0.907; p<0.0001).

The volume decrease in the number of PCI procedures in the CCS setting was also significant (p<0.0002) yielding the IRR of 0.923 (95% CI: 0.885 - 0.964), but much less extensive than drop in the number of admitted CCS patients. The total number of coronary artery bypass grafting (CABG) cases decreased from 1,113 per year in the pre-pandemic period to 894 per year during the pandemic period (IRR 0.802), but data about preoperative conditions of patient, ACS or CCS, are not available.

Furthermore, frequency of some advanced interventional procedures that develops in Croatia rapidly during the last decade, such as transcatheter closure of atrial septal defect (ASD), percutaneous transluminal septal myocardial ablation (PTSMA) or percutaneous myocardial biopsy remained similarduring the both periods. In contrast, transcatheter aortic valve implantation (TAVI) procedures increased significantly, from 91 per year in the pre-pandemic period to 183 per year in the pandemic period thus yielding the IRR 2.010 (95% CI: 1.556 - 2.615; p<0.0001) (Table 3).

Table 3. Incidence rate ratios and number of interventional cardiology procedures and CABG and advanced interventional procedures performed during the pre-pandemic and pandemic COVID-19 period.

Variable	Pre-pandemic N per year (2017 to 2019)	Pandemic N per year (2020 to 2012)	IRR (95% CI)	P-value
CAG and CC	25,938	20,134	**0.776** (0.762 – 0.791)	**<0.0001**
PCI, total	8,633	8,505	0.985 (0.956 – 1.015)	0.3402
PCI in ACS	4,214	4,424	**1.050** (1.006 – 1.095)	**0.0238**
PCI in CCS	4,419	4,081	**0.923** (0.885 – 0.964)	**0.0002**
CAG in ACS without PCI	1,266	1,058	**0.836** (0.769 - 0.907)	**<0.0001**
CABG	1,113	894	**0.802** (0.734 - 0.877)	**<0.0001**
TAVI	91	183	**2.010** (1.556 - 2.615)	**<0.0001**
ASD closure, transcatheter	61	47	**0.770** (0.515 - 1.146)	0.1796
PTSMA	10	3	**0.300** (0.0530 - 1.165)	0.0574
Endomyocardial biopsy	264	244	**0.924** (0.773 - 1.104)	0.3753

Abbreviations: ACS-acute coronary syndrome; ASC-atrial septal defect; CAG and CC-coronary angiography and cardiac catheterisations; CABG-coronary artery bypass grafting; CCS-chronic coronary syndrome; PCI-

percutaneous coronary intervention; PTSMA-percutaneous transluminal septal myocardial ablation; TAVI-transcatheter aortic valve implantation;.

As shown in Table 4, in-hospital imaging diagnostic procedures such as transesophageal echocardiography (TEE), which inherently carries a high-risk for COVID-19 spread did not decrease during the pandemic period but instead it significantly increased among hospitalized patients, from 3,981 cases per year in the pre-pandemic period to 4,357 per year in the pandemic period yielding the IRR 1.094 (95% CI: 1.048 - 1.143; p<0.0001). On the other hand, the utilization of in-hospital transthoracic echocardiography (TTE) decreased significantly in the pandemic *versus* pre-pandemic period. Cardiac MR performed for admitted patients significantly increased from 283 per year in the pre-pandemic period to 369 per year in the pandemic period by IRR 1.304 (95% CI: 1.114 - 1.528; p<0.0008), while coronary CT angiography (CCTA) and calcium scoring utilization significantly decreased from 374 per year in the pre-pandemic period to 318 per year in the pandemic period by IRR 0.850 (95% CI: 0.730 - 0.990; p<0.0333) (Table 4).

The use of standard laboratory tests for risk stratification among patients with suspected coronary disease such as lipid profile decreased significantly during the pandemic period by IRR 0.833 (Table 4).

On the other hand, the utilization of troponin testing, most used laboratory diagnostic test for the work-up of acute chest pain, performed across all Croatian hospitals, increased significantly during the pandemic *versus* pre-pandemic period by the IRR 1.045 (95% CI: 1.036 - 1.054; p<0.0001).

The use of the gold standard laboratory test for the diagnosis of heart failure, natriuretic peptide testing, exhibited the most prominent and significant increase in use during the pandemic *vs.* pre-pandemic period with more than doubling in IRR (2.158, 95% CI 2.122-2.194).

Table 4. Incidence rate ratios of utilization of cardiovascular imaging modalities and common laboratory tests during the pre-pandemic and pandemic COVID-19 period.

Variable	Pre-pandemic N per year (2017 to 2019)	Pandemic N per year (2020 to 2012)	IRR (95% CI)	P-value
TTE	55,003	46,880	**0.852** (0.842 - 0.863)	**<0.0001**
TEE	3,981	4,357	**1.094** (1.048 - 1.143)	**<0.0001**
CTCA/calcium scoring	374	318	**0.850** (0.730 - 0.990)	**0.0333**
Cardiac radionuclide imaging	133	105	0.797 (0.612 - 1.036)	0.0811
Cardiac MRI	283	369	**1.304** (1.114 - 1.528)	**0.0008**
Lipid profile	260,392	217,043	**0.833** (0.829 - 0.838)	**<0.0001**
Troponin testing	103,504	108,181	**1.045** (1.036 - 1.054)	**<0.0001**
Natriuretic peptide testing	19,830	42,787	**2.158** (2.122 - 2.194)	**<0.0001**

Abbreviations: CTCA-computerized tomography coronary angiography; MRI-magnetic resonance imaging; TEE-transesophageal echocardiography; TTE-transthoracic echocardiography.

During the pandemic period, hospital admissions of patients with 2nd/3rd degree atrioventricular block (1,567 per year) remained similar compared to the pre-pandemic period (1,489 per year), as provided in Table 5.

Table 5. The number of admitted patients due to bradycardia/heart atrioventricular blocks, atrial fibrillation/flutter and utilization of pacemaker and ICD implantations during the pre-pandemic and pandemic period.

Variable	Pre-pandemic N per year (2017 to 2019)	Pandemic N per year (2020 to 2012)	IRR (95% CI)	P-value
AV block (2nd/3rd°) admissions	1,567	1,489	0.950 (0.885 - 1.021)	0.1582
SSS admissions	448	356	**0.795** (0.689 - 0.915)	**0.0012**
Pacemaker implantation	3,467	2,936	**0.847** (0.806 - 0.890	**<0.0001**
ICD implantations	608	699	**1.150** (1.030 – 1.284)	**0.0118**
Atrial fibrillation/ flutter admissions	4,839	4,029	**0.833** (0.798 - 0.868)	**<0.0001**

Abbreviations: AV-atrioventricular; ICD-implantable cardioverter defibrillator; SSS-sick sinus syndrome.

However, hospital admissions because of sick sinus syndrome decreased significantly, from 448 per year in the pre-pandemic period to 356 per year in the pandemic period by IRR 0.795 (95% CI: 0.689 - 0.915). Consequently, pacemaker implantation (VVI and DDD modes) procedures decreased significantly, from 3,467 per year in the pre-pandemic period to 2,936 per year in the pandemic period by IRR 0.847 (95% CI: 0.806 - 0.890). Increasing number of implantable cardioverter defibrillator (ICD) implantations last decade in Croatia, continued to increase in analyzed periods, from 608 per year in the pre-pandemic to 699 per year in the pandemic period yielding the IRR of 1.150 (95% CI: 1.030 – 1.284; p<0.0118) (Table 5).

4. Discussion

The COVID-19 pandemic has exerted a profound impact on health care system, especially non-COVID-19 hospital admissions, encompassing both acute and elective cases, as well as the volume of procedures performed for admitted patients. Notably, cardiovascular diseases, globally recognized as a leading cause of morbidity and mortality, were disproportionately affected. A systematic review by Samuel Seidu et al. revealed a substantial decline in admissions for various cardiovascular diseases worldwide, particularly for myocardial infarction (MI), acute coronary syndrome (ACS), and stroke. The magnitude of these reductions varied, reaching up to 73% [8]. However, most studies included in his review were published in 2020, with only a minority in 2021 (8.7%).

A comprehensive Croatian study conducted at the end of 2020 underscored a 21% decrease in the total number of hospital admissions, with reductions observed across all major diagnostic categories, except for respiratory diseases [5]. Notably, the most significant decrease was observed in eye diseases (46%), while cardiovascular diseases, specifically categorized as "circulatory diseases," showed a 21% decline. Within the cardiovascular domain, non-elective diagnostic-related group (DRG) classes for stroke, transient ischemic attack, and heart failure, including cardiogenic shock, saw decreases of 15%, 27%, and 13%, respectively. Concurrently, a 27% decrease in procedures related to circulatory disorders was recorded [5].

The pandemic period witnessed a global decline in hospital admissions for heart failure (HF), ranging from 23.4% to 62% [8]. In Croatia, our study identified a significant 9% decrease (Incidence Rate Ratio [IRR] 0.909), although this reduction was notably less than the worldwide average. Similarly, global admissions for ACS patients substantialy decreased (40–50%) [9], while in Croatia, as our data show, the reduction was only about 10% (IRR 0.895), considerably smaller than reported in similar studies worldwide.

Specifically focusing on ACS subtypes, a pronounced decrease in STEMI admissions was observed globally (21–56%) [7,8], with the Croatian experience indicating lower, 15% reduction (IRR

0.845). Even more, systematic review and meta-analysis carried out by Kamarullah et al. showed even higher global drop of STEMI admissions during pandemic reaching even 80% in some circumstances [10]. Notably, data from Croatia demonstrated a relatively modest decline in STEMI admissions compared to other countries. For example, except of one single-center study in Germany [11] and one study conducted in three administrative regions in Western France [12], Croatia showed the smallest decrease in STEMI admissions during pandemic period, much likely due to well-established national primary PCI network [13]. The fall in the number of admitted NSTEMI patients was also recorded worldwide, from 33% to 66% [7,8]. However, during two pandemic years, the number of admitted NSTEMI patients in Croatia was not decreased at all according to our data (IRR 0.971). Unstable angina (UA) patients' admissions during pandemic were not recorded in the literature systematically. As the less symptomatic part of ACS spectrum, it would be reasonable to expect the largest drop in admissions for patients presenting with UA. This trend was confirmed in other European countries such as Western Germany during the government-imposed lock-down period by -23% [14], and in two single center studies, one from Switzerland where a rise of 37% was recorded [15], and another study from India where a significant decrease was observed [16]. In line with these expectations, we observed a significant drop in UA admissions in our national dataset and this decline was the greatest across all ACS subtypes, by the magnitude of 20%. Concomitantly, the utilization of cardiac troponin tests in Croatian hospitals did not decrease but it rather increased significantly thus suggesting that most of the patients were likely correctly stratified.

Data on the impact of COVID-19 pandemic on routine scheduled admissions for CCS are generally lacking as most of the studies were focused on emergency departments. Our study clearly showed a sharp drop in admissions for CCS in Croatia, occurred with the magnitude of -44%. In fact, the reluctance to seek hospital care as well as general delay in non-emergency admissions resulted in more than 2000 less admissions for CCS per year during pandemic period (IRR 0.657).

Ultimately, the most crucial outcome for patients with coronary artery disease was the implementation of interventions. According to the systematic reviews and meta-analysis conducted by Kamarullah et al. there was a substantial decline of 72% (ranging from 53% to 97%) in the rate of performed primary percutaneous coronary interventions (PCIs) during the pandemic [10]. In contrast, our results indicate that the pandemic did not influence the overall number of PCIs performed in Croatia (IRR 0.985. . Interestingly, the number of PCIs conducted in the context of acute myocardial infarction (AMI) even significantly increased in Croatia, with an IRR of 1.050. This surge can be attributed to the rejection of the initial literature recommendations favoring thrombolysis by most of Croatian cardiologists, and the swift adoption of early recommendations by the Croatian Cardiac Society, emphasizing primary PCI under personal protective measures [17]. In tandem with the drop in routine scheduled admissions for chronic coronary syndrome in Croatia, there was a notable decrease of 22% in the total number of coronary angiographies, consistent across both pandemic years. Comparatively, an international survey across 108 countries revealed a more extensive global decrease of 55% [18]. While the number of PCIs in the setting of chronic coronary syndrome in Croatia experienced a significant decrease (IRR 0.923), this reduction of 7.7% was considerably less than the decrease in chronic coronary syndrome patients (44%), suggesting that less stable CCS patients still received appropriate care during the pandemic period. The pandemic also saw a reduction in the number of patients undergoing coronary bypass surgery (CABG). In Croatia 19.8% less CABG procedures was performed (IRR 0.802) in pandemic period. However, such decline was less pronounced than in other countries, for example in Ireland, CABG was performed at 61% of the expected rate in 2020 [19], while in the UK, there was a 51% decline during the lockdown [20]. In Brazil, there was a 25% reduction in CABG procedures in 2020 [21], and the USA witnessed a 35.5% decline in the number of patients undergoing CABG [22]..

Anticipated decreases in cadaveric heart registrations and transplants during lockdowns and pandemics were observed globally. A population-based study by Aubert et al., covering 22 countries, reported a decrease in heart transplant rates between 2019 and 2020, ranging from -5.46% to even up to -88.89% worldwide [23]. Across United States, rates of heart registrations and transplants decreased by 28% and 13%, respectively, during the first two global waves of COVID-19 pandemic

[24]. In Croatia, data from CHIF database contradicts this trend, revealing a higher number of heart transplants performed in Croatia in pandemic compared to pre-pandemic period (36 *vs.* 32 cases), showing a non-significant increase of 9.4%. In line with this, during the pandemic period, advanced techniques for heart failure (HF) treatment in Croatia, such as cardiac resynchronization therapy (CRT), saw a significant increase of almost 23% (IRR 1.229), while the utilization of ventricular assist devices (both for left and right ventricle support) remained virtually unaffected by the pandemic conditions (IRR 0.926). These findings underscore the continuity of work by highly skilled teams of cardiovascular professionals in adapting to challenging pandemic circumstances.

It is anticipated that structural interventional procedures would also experience a decline during pandemics. Global data suggests that Transcatheter Aortic Valve Implantation (TAVI) activity decreased by nearly 20% worldwide during the initial months of lockdown compared to the same pre-pandemic period [25]. In contrast, our data show that TAVI procedures in Croatia doubled during the pandemic period (IRR 2.010). This surge coincided with significant reimbursement efforts by the Croatian Ministry of Health during the early pre-pandemic and pandemic periods. Croatian cardiologists seized the opportunity to enhance their professional endeavors despite the challenges posed by the pandemic, leading to a substantial increase in TAVI utilization. Other advanced interventional procedures, such as transcatheter closure of atrial septal defects, percutaneous transluminal septal myocardial ablation, percutaneous myocardial biopsies, and ventricular assist device (LVAD and RVAD) implantations, remained consistent in both periods. In contrast, Ireland for example experienced a 50% decrease in the latter [21]. As expected, there was a significant increase in extracorporeal membrane oxygenation (ECMO) procedures during the pandemic period, rising by IRR 1.355.

At the onset of the pandemic, an elevated incidence of bradycardia and relative bradycardia was reported in patients with COVID-19 infection, and an increase in pacemaker (PM) implantations was expected [26]. It was observed that among COVID-infected patients, most devices were implanted due to high-degree or complete atrioventricular block (67.5%), with a smaller percentage attributed to sick sinus syndrome (SSS) (18.7%) [27]. However, a pan-European observational registry across 15 centers from 12 countries revealed a relative decrease in the percentage of bradycardia/atrioventricular blocks (AVB) in acute cardiac settings from 14% in 2019 to 11% in 2020, with an absolute decrease by 50% (IRR 0.50). [4]. Concurrently, during pandemic in Croatia overall hospital admissions of patients with 2nd/3rd degree AVB remained similar to the pre-pandemic period (IRR 0.950), while admissions due to sick sinus syndrome decreased significantly (IRR 0.795). Considering that AVBs primarily have urgent indications and SSSs mostly elective indications for pacemaker implantations, the Croatian healthcare system effectively addressed patients with acute settings related to bradycardia/AVB during the pandemic. Aldoughth during pandemic in Croatia pacemaker implantations procedures (VVI and DDD) decreased significantly by around 15%, this decline was more moderate than those reported in other studies. For instance, a survey conducted by the Italian Association of Arrhythmology and Cardiac Pacing revealed that 50% of centers reported a reduction of more than 50% in elective pacemaker implantations [28]. Similar trends were observed in a Spanish study, with a total decrease of 35.2% in the number of preferential/urgent pacemaker implantations [29]. Regional studies further supported these findings, showing significant reductions in pacemaker implantations, including a 28% decrease in the Veneto Region in Italy [30], a 42.3% decrease in overall procedures in Southern Italy [31], a 73% reduction in one Peruvian clinical hospital center [32], and a 54.7% decrease across nine hospitals in Catalonia [33]. Concerning the rates of implantable cardioverter defibrillator (ICD) implantations during the COVID-19 pandemic, some data are available. For example, in Italy, 92.9% of centers reported a reduction in the number of implantations for primary prevention and 72.6% for secondary prevention [28]. Contrary to this trend, increase in the number of ICD implantations in Croatia was significant with 15% rise during pandemic compared to pre-pandemic period (IRR 1.150).

Atrial fibrillation (AF) stands as the most prevalent sustained cardiac tachyarrhythmia and a common condition prompting medical attention in adults. The current estimated prevalence of AF in adults ranges between 2% and 4% [34], with a lifetime risk of approximately 1 in 3 individuals of

European ancestry at the index age of 55 years [35, 36]. A pan-European observational registry focusing on acute cardiac settings during pandemics indicated a notable decrease of more than 30% in patients with atrial arrhythmias, reflected in an IRR of 0.69 [32]. Simultaneously, hospital admissions for atrial fibrillation and atrial flutter also experienced a significant reduction in Croatia, albeit to a lesser extent compared to other countries, with an IRR of 0.833 indicating less non-diagnosed cases and less patients with missed anticoagulant medicatications and subsequent stroke.

Regarding the standard cardiovascular imaging procedures, an international survey conducted among 909 centers in 108 countries reported a decrease in cardiovascular procedures by 42% from March 2019 to March 2020 and a further reduction of 64% from March 2019 to April 2020 [20]. Specifically, transthoracic echocardiography (TTE) procedures decreased by 59% in this global assessment. Our data, limited to admitted patients, reveals a 0.852 Incidence Rate Ratio (IRR) denoting a decrease in TTE procedures during the pandemic. Concurrently, biochemical tests for heart failure patients, such as natriuretic peptides, more than doubled with an IRR of 2.158. Conversely, some routine biochemical tests in coronary patients, like lipid profiles, significantly decreased in Croatian hospitals, yielding an IRR of 0.833. In the aforementioned survey, transesophageal echocardiography (TEE), deemed high-risk for COVID spread, experienced a 76% decrease. However, our study in the Croatian hospital population revealed a surprising increase in the number of TEE procedures during the COVID-19 pandemic, with an IRR of 1.094. During the pandemic, worldwide computed tomography angiography (CCTA) saw a significant reduction by 54% [20], but   this reduction was significantly lower than that observed for exercise stress tests (84%), suggesting the final   higher utilization of non-stress modalities for coronary artery disease assessment [37]. Majority of CCTA procedures in Croatia occurred in an outpatient setting, and although these specific data are unavailable for our study, among Croatian in-hospital patients, a significant decrease in CCTA utilization was observed (IRR of 0.850), but again with less extent than in other countries. . In the USA, the pandemic saw a 72% decrease in the number of cardiac magnetic resonance imaging (CMR) procedures [19]. Similar trends were observed in certain centers in southern Italy, reflecting a significant reduction in cardiac MRI procedures [38]. Assessing the presence and severity of myocardial injury, CMR emerges as a clinically valuable diagnostic tool, and in contrast to global trends, Croatia experienced an increase in in-hospital CMR imaging from 2019 to 2021, reflected in an IRR of 1.304.

It's challenging to fathom that in Croatia, the reluctance of patients to seek hospital care due to the fear of infection, government-imposed stay-at-home orders, and alarming media reports had a significantly lesser impact on the population compared to other countries. Initially, the intention to spare an already overburdened healthcare staff and system, though seemingly more important at the outset, likely diminished over the time [39]. This trend, observed in various societies, probably mirrored the situation in Croatia.

These favorable outcomes in dealing with the pandemic in Croatia, compared to many other countries, can be attributed to the Ministry of Health's strategy to centralize COVID patients in newly established regional "COVID-19 hospitals." Simultaneously, other hospitals continued to manage "regular" or COVID-negative patients. The concentration of COVID-positive patients in specialized facilities, coupled with the ability of the Croatian healthcare staff to navigate catastrophic situations honed through experiences from the Homeland War during 1990s and two recent earthquakes in Croatia [40], empowered cardiovascular health professionals in Croatia to organize more effectively in extreme situations than in routine ones.

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