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Mortality After Arterial Stenting at Short- and Long-Term Follow-Up

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Abstract

The review presents mortality rates after arterial stenting in the short and long term follow-up. From 277,388 publications covering a 24-year period from 1998 to 2024, 41 sources were selected, which reviewed 1157 sources (for 1971-2024). According to the final data of 479695 observations after arterial stenting, mortality was 4.7% (22437 people died) and it ranged from 0.59% to 46.5%. According to the observation period, the mortality rate was as follows: 30 days - 2.4% (43 died); first year – 1.2% (1436); 2nd year - 0.4% (493), 3rd year -10,2% (14494); 4-5 years – 2% (1635); 6 years – 1.7% (72); 7-10 years -18.5% (4264). A number of researchers have reported high mortality rates, ranging from 13.8% to 46.5%. The pooled analysis revealed the three most significant increases in mortality - in periods up to 30 days (2.4%), third year (10,2%) and 7-10 years (18.5%). Taken together, the results of the study on the mortality statistics of patients after angioplasty provide valuable information about the effectiveness, safety and allow us to assess its significance and develop the most appropriate tactics and methods of treatment.

Keywords: Mortality; Stenting; Angioplasty; Heart failure; Artery; Coronary artery; Carotid artery.
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1. Introduction

Cardiovascular diseases (CVD) are the leading cause of death worldwide, accounting for an estimated 17.9 million deaths each year. More than four out of five CVD deaths are due to heart attack and stroke, with one-third of these deaths occurring prematurely and in people under 70 years of age.[1]

Currently, the treatment of choice for atherosclerosis of the coronary artery is stenting and, when stenting is not possible, coronary artery bypass grafting. An analysis of the global coronary stent market showed that its volume was USD 9.76 billion in 2024 and is expected to reach approximately USD 17.40 billion by 2034, growing at a CAGR of 6% from 2024 to 2034.[2] In coronary artery stenting, the metal segment dominates the market with a revenue of about $7.5 billion in 2023, expected to grow to $13 billion by 2032. It has advantages such as lower stent rupture rates, flexibility, and biocompatibility.[3]

The key segments of coronary stents are bare metal coronary stents, bioresorbable coronary stents, coronary covered stents, and drug-eluting coronary stents. In 2023, drug-eluting coronary stents accounted for the largest share of the coronary stent market.[4] On the basis of product, the drug-eluting stent segment will be the driving force behind the market growth in the coming years, and this segment is expected to hold a dominant position during the forecast period. The availability of new drugs in this segment is leading to an increase in the adoption of the product.[5]

Thus, the treatment of atherosclerotic arterial lesions is one of the major healthcare concerns, especially in the elderly population. The pace of development and implementation of coronary stenting is impressive, prolonging the lives of millions of people. Despite significant improvements in stent design, improved functional assessment of coronary artery lesions and the use of intravascular imaging, morbidity and mortality remain significant. The results of numerous studies have shown that stenting of arterial vessels is associated with various complications in the near and distant periods, which lead to poor results. These include mortality, re-infarction, stent thrombosis, restenosis, vascular damage, stent damage and fracture, insufficient stent expansion, plaque opening and rupture, neoatherosclerosis, *etc*. The main disadvantage of stenting is mortality and the presence of the stent metal structure in the lumen of the artery as a foreign body, the

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atheroma is not removed, *i.e*. the technique is essentially palliative. Among them, lethal outcomes deserve special attention. In this regard, the study of fatal outcomes after stenting of the heart artery at different observation periods is of significant scientific and practical interest.

The purpose of this review is to conduct a systematic analysis of fatal outcomes after arterial stenting in the short and long term.

2. Materials and methods

We conducted a systematic review and meta-analysis of all randomized controlled trials that reported results on mortality of patients after arterial stenting at long-term and long-term follow-up.

A total of 277,388 publications were analyzed, covering a 24-year period from 1998 to 2024, containing the keywords: mortality, stenting, angioplasty, cardiac mortality, artery, coronary artery, carotid artery, by platform: Web of Science - 1469, PubMed - 6653, Scopus - 3128, Google Scholar - 266000, ScienceDirect - 138 journals and books. From these publications, 41 publications were selected that were directly related to mortality after arterial stenting. Collectively, these articles cover reviews of 1157 publications over the period 1971-2024. The analysis was carried out taking into account the follow-up period after angioplasty using a stent: up to 30 days, one year, 2 years, 3 years, 4-5 years, 6 years, 7-10 years.

3. Results

3.1 Mortality after stenting up to 30 days

In 560 patients (119 women and 441 men) undergoing stenting over 3 years, cardiac death or myocardial infarction within 30 days after surgery occurred in 5% of women and men, and the composite endpoint of death, myocardial infarction, or revascularization was observed in 24 % and 26%, respectively.[6] (Table 1)

According to clinical data obtained in 607 patients with unprotected stenosis of the left main coronary artery who underwent percutaneous coronary intervention (PCI), the 30-day mortality rate was 8 (1.3%).[7]

Among 316 patients with STEMI, 247 (78%) developed STEMI after coronary stent implantation due to stent thrombosis. Hospital mortality in the ST group was 0.8%, and in the group without ST - 1.4% (P>0.05).[8] Similar figures were obtained in a study of 301 (4.9%) elderly patients (> or = 80 years), hospital mortality was 1.33% .[9]

All the studies reviewed here by four authors, covering 1784 patients during the period 2003-2014 who underwent stenting, confirm that the mortality rate is quite high and is 2.4%) (Fig. 1).

Table 1: Dynamics of mortality after stenting during different periods of observation.

No	Authors	Publication coverage			Observation period,	Number of observations	Mortality	
		Publication year	Quantity	Period			Absolute number	%
Observation periods up to 30 days								
1	Moriel M., Feld S.,[6]	2003	18	1982-2009	30 days	560	28	5
2	Alfonso F.[7]	2011	26	2007-2020	30 days	607	8	1,3
3	Li X. W., Liu Y., *et.al*[8]	2022	29	1989-2001	30 days	316	3	0.8
4	Chauhan M. S., Kuntz R. E.,[9]	2001	25	1994-2000	30 days	301	4	1,33
	Total:		98	1982-2020	-	1784	43	2,4
Observation period up to a year								
5	De Gregorio J., Kobayashi Y.,[10]	1998	35	1991-1997	1	137	12	9
6	Black A., Cortina R.,[11]	2001	34	1972-2000	7 months	92	4	4

No	Authors	Publication year	Publication coverage: Quantity	Publication coverage: Period	Observation period,	Number of observations	Mortality: Absolute number	Mortality: %
7	Puymirat E., Labèque J. N.,[12]	2008	30	1975-2006	1	24	2	8,3
8	Sukiennik A., Ostrowska-Nowak J.,[13]	2008	N/a		up to a year	71	17	23,9
9	Ali L., Malik S. N.,[14]	2014	24	2002-2013	3 months	53	1	1,9
10	Murat C., Jawed P., *et.al*[15]	2022	25	2006-2021	1	35389	455	1,3
11	Silvestri M., Barragan P.,[16]	2002	36	1978-1999	1	140	15	11
12	Wang H., Xie X., *et.al*[17]	2022	23	2009-2022	1	1795	22	1,22
13	Skorupski W. J., Kałużna-Oleksy M., *et.al*[18]	2022	38	1971-2021	1	396	83	21
14	Zhu J, Rao A, Berger K,[19]	2024	30	1998-2023	1	70237	414	0,59
15	Georges D, Kreft D,[20]	2024	37	2006-2023	1	5451	411	7.5
	Total:		312	1971-2023	-	113 785	1436	1,2
	Follow-up period up to 2 years							
16	Voudris V. A., Skoularigis J. S.,[21]	2002	N/a		2	402	152	38
17	Jassim Al Suwaydi 1 D. R. H. J.,[22]	2004	33	1998-2001	1 year, 8 months	5130	30	0,59
18	Cerrato E., Pavani M.,[23]	2021	36	1994-2020	2	106592	311	8.2

No	Authors	Publication year	Publication coverage		Observation period,	Number of observations	Mortality	
			Quantity	Period			Absolute number	%
	Total:		69	1994-2020	-	112124	493	0,43
				Follow-up period up to 3 years				
19	Batyraliev T. A., Fettser D. V.,[24]	2009	N/a		3	124	7	5,6
20	Wang Q., Tan Q.,[25]	2014	N/a		3	79	6	7,6
21	Sofia Nestler D. K., Peter Donndorf,[26]	2022	15	2002-2019	3	32538	12102	37,2
22	Philip, F, S.*et al.*[27]	2016	46	1997-2014	3	9673	80	0,83
23	Georges D, Kreft D,[20]	2024	37	2006-2023	3	8021	913	11,4
24	Moroni F, Seth M, Changezi HU,[28]	2024	16	1999-2022	3	91308	1386	1,5
	Total:		114	1997-2023	-	141 743	14 494	10,2
				Follow-up period up to 4-5 years				
25	Ohya M., Kadota K.,[29]	2017	24	1986-2016	4,6	1607	27	1,71
26	Nevio Taglieri 1 A. G. B.,[30]	2020	29	1994-2018	3,5	75754	636	0,84
27	Lyden S. P., Brodmann M.,[31]	2022	36	2004-2020	4	589	81	13,8
28	Velibey Y., Guvenc T. S.,[32]	2016	19	1975-2016	5	300	52	17,3
29	Columbo, JA and *et al.*,[33]	2019	25	1972-2016	5	4415	808	18,3
30	Hausegger K, Kurre W,[34]	2024	29	2008-2023	5	204	31	15

No	Authors	Publication year	Publication coverage		Observation period,	Number of observations	Mortality	
			Quantity	Period			Absolute number	%
	Total:		162	1972-2020	-	82 869	1635	2
				Follow-up period up to 6 years				
31	Ali M., Hanley A.,[35]	2013	19	1993-2006	6	158	24	15
32	Gaudino M., Hameed I.,[36]	2021	30	2005-2021	6,2	4134	48	1,17
	Total:		49	1993-2021	-	4292	72	1,7
				Follow-up period up to 7-10 years				
33	Kohsaka S., Goto M.,[37]	2008	29	1986-2020	1-9	3917	43	1,1
34	Buszman P. E., Buszman P. P.,[38]	2009	25	1983-2009	10	252	78	31,1
35	Kubo S., Kadota K.,[39]	2013	N/a		7	182	20	11
36	Chew N. W. S., Ng C. H.,[40]	2022	46	2002-2022	10	4595	551	12
37	Hironori Hara M., Masafumi Ono,[41]	2022	N/a		10	893	280	31,4
38	Hetherington I., Totary-Jain H,[42]	2022	169	1978-2022	10	1102	272	24,7
39	Garg, A., *et al*.,[43]	2021	26	2008-2020	8	4499	49	1,1
40	Rheude, T., *et al*.,[44]	2022	28	1994-2022	10	4953	2303	46,5
41	Tineke H. Pinxterhuis, *et al*.,[44]	2024	30	1991-2020	10	2705	668	24,7
	Total:		353	1978-2022	-	23 098	4 264	18,5
	Total:		**1157**	**1971-2024**		**479695**	**22437**	**4,7**

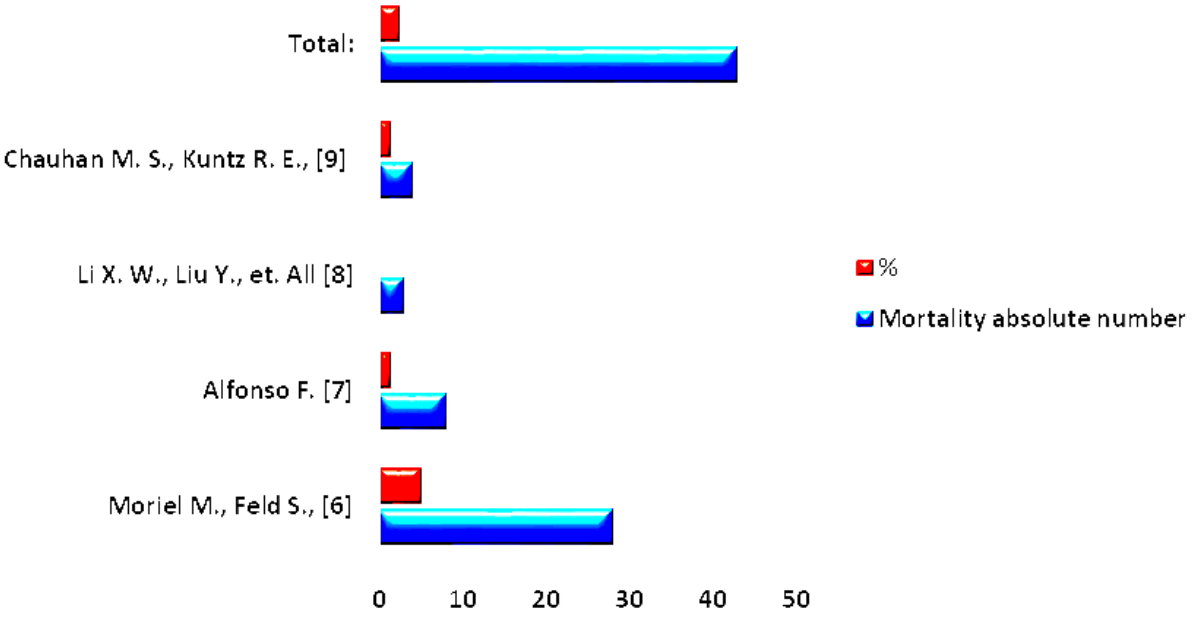

Fig. 1: Mortality after stenting within 30 days according to 4 publications.

3.2 Mortality after stenting during follow-up periods of up to one year

Overall survival of patients over 75 years of age (n=137) 12 months after coronary artery stenting was 91% and disease-free survival was 54%, and these patients are considered high risk, the complication rate was higher, and death was observed in 12 (9 %).[10]

Other studies concluded that when revascularization of unprotected left main coronary artery (LMCA) was performed in 92 consecutive patients, the in-hospital mortality rate was 4 (4%).[11] During the year, 2 deaths (8.3%) were registered among 24 patients with contraindications to surgery and unprotected stenosis of the left coronary artery after installation of stents.[12] In a number of studies, including 71 patients treated for acute disease of the left main coronary artery (LTCA), a fairly high mortality rate of 23.9% was recorded.[13]

Of the 53 patients who underwent percutaneous stenting of the left main coronary artery, one patient (1.9%) died after three months.[14] A comprehensive, single-arm, prospective, multicenter study with 3-month and 1-year follow-up was conducted in 37,198 patients (Europe 69.2%, Asia 17.8%, Africa/Middle East 6.6%, and South America/Mexico 6.5%). Of the total number, 35,389 patients (95.1%) were under observation after one year. Patients were enrolled between October 2014 and June 2018 in 378 hospitals in 50 countries. The study evaluated the effectiveness of a new generation coronary stem containing sirolimus-releasing stems with an aluminized biodegradable polymer. Target lesion failure (TLF) at 1 year, identified as a combination of cardiac death, target-vessel myocardial infarction, and target-lesion revascularization. TLF is observed in 3.2% of patients, cardiac death in 1.3% (455/35389), death from all causes in 2.1% (746/35389).[15]

A total of 140 patients with unprotected truncus arteriosus stenosis were consecutively selected and underwent elective stenting. Group I included 47 patients with a high risk of coronary artery bypass grafting (CABG), and group II included 93 patients with a low risk of coronary artery bypass grafting (CABG). The annual mortality rate was 11% and 2.5%, respectively (survival rate was 89% in the first 29 patients of group I and 97.5% in the first 63 patients of group II).[16]

In a study of 1795 participants with diabetes, in which 912 patients were assigned to polymer-free amphyllimus-eluting stents (AES) and 883 patients were assigned to durable polymer revascularization (ZES), the mortality rate was 22 (1.2%) one year later.[17] In 396 patients who underwent PCI, the all-cause mortality rate was 83 (21%).[18]

Transcarotid artery revascularization (TCAR) and transfemoral carotid artery stenting (TFCA) were studied in 70237 patients (TCAR=58.7%, TFCA=41.3%), with survival observed in the first 6 months (HR=0.59, 95% CI = 0.53-0.62, p<0.001).[19] Within one year of the first drug-eluting stent (DES) implantation, 411 patients out of 8,451 died.[20]

Thus, when analyzing 11 studies for the period from 1998 to 2024 with the participation of 113 785 patients Mortality up to one year after stenting ranged from 1.22% to 23.9% and averaged 1,2% (1436 died) (Fig. 2). High mortality rates within a year after stenting (8.3%, 9%, 21% and 23.9%) are probably associated with the initial stage of mastering angioplasty.

3.3 Mortality after stenting during follow-up up to 2 years

Data from several studies indicate a fairly high mortality rate within the specified time frame. Among 402 patients with coronary artery disease who underwent coronary artery stenting in 69 elderly people (age >70 years), after 2 years the mortality rate was 38%, and in the group younger than 333 younger people (age <70 years) it was 24% (P < 0.001).[21]

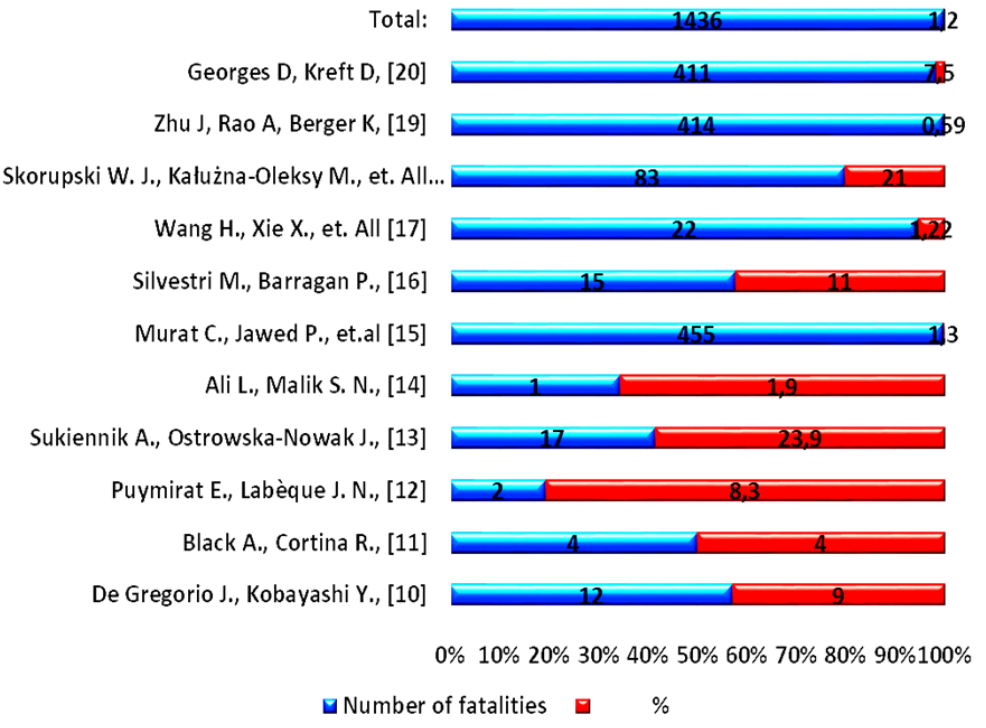

Fig. 2: Mortality after stenting within a year according to 11 authors in 1436 observations.

Most of the previous 23 studies involving 10,347 patients, reports the results of percutaneous coronary interventions in 5,130 patients. The authors presented a two-year overall mortality rate of 0.59%; (95% CI 0.50–0.70, P<0.001).[22]

There is a relatively small body of literature devoted to perforation of the coronary arteries during PCI as a cause of death. A review study by a number of authors reported 311 perforations of the coronary arteries during angioplasty among 106,592 patients, which led to death in 7.2% of patients.[23]

In conclusion, an analysis of studies for the period from 2002 to 2021 involving 112124 patients showed that Mortality within two years after stenting ranged from 0.59% to 38% and averaged 0.43% (493 died) (Fig. 3).

3.4 Mortality after stenting during follow-up up to 3 years

During follow-up periods of up to 3 years, mortality after stenting differs compared to previous groups, which corresponds to the highest rates. During a 3-year follow-up of 124 patients after implantation of standard metal stents (SMS) into an unprotected stem cell, death from cardiac causes was recorded in 5.6% of cases.[24] In 79 elderly patients with unprotected left main coronary artery stenosis who underwent percutaneous coronary intervention (PCI) using drug-eluting stents for unprotected left main coronary artery disease, cardiac death occurred in 6 (7.6%) patients.[25]

Mortality studies have been conducted during the first three years after initial coronary intervention. As the analysis shows, out of 32,538 patients with coronary heart disease, 12,102 (37.2%) died.[26] Data from multiple sources found significant reductions in cardiac mortality (0.83%, 80 died) associated with second-generation DES compared with BMS after 3 years of 9673 people studied.[27]

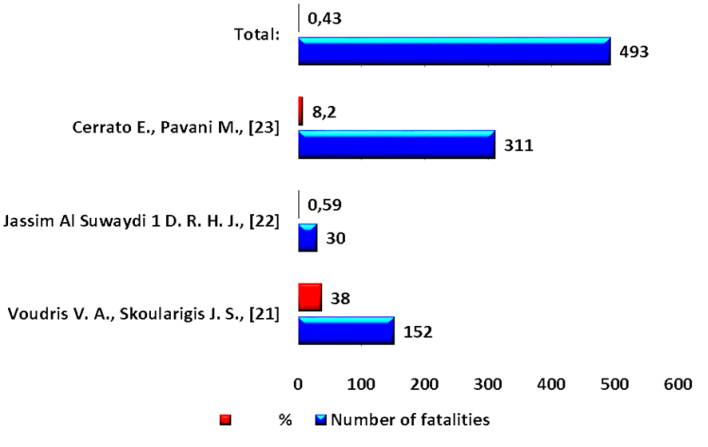

Fig. 3: Mortality after stenting with a follow-up of up to 2 years among 112 124 observations according to three authors.

Within three years after drug-eluting stent (DES) implantation, 913 (11.5%) of 8021 patients died.[20] A research group that analyzed deaths after PCI that occurred at 39 Michigan hospitals found that out of 91,308 patients, 1386 (1.5%) died during a three-year follow-up period.[28]

In total, an analysis of data from 6 publications for 1997-2023 involving 141 743 patients after stenting during a follow-up period of up to 3 years, the mortality rate was 10,2% (14 494 died) (Fig. 4)

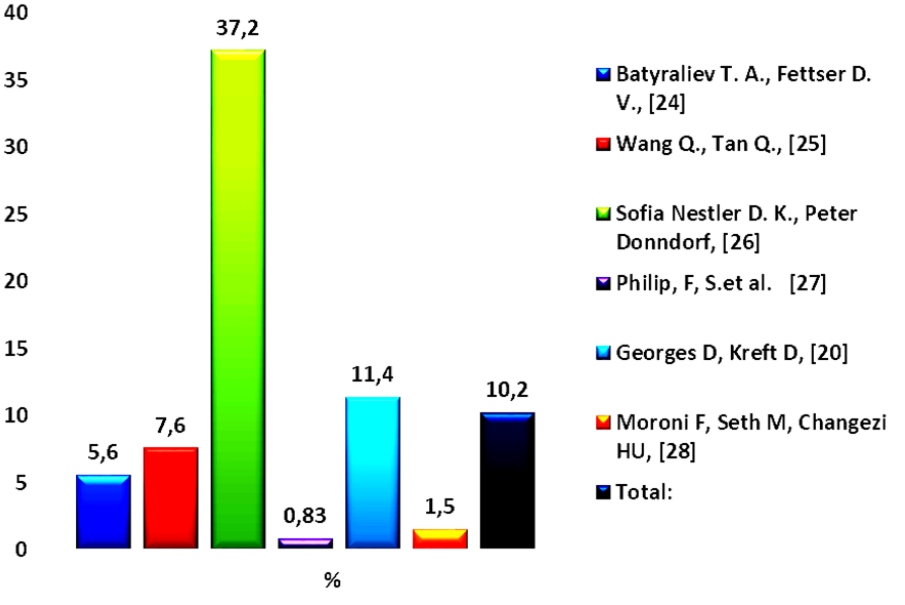

Fig. 4: Mortality after stenting with a follow-up of up to 3 years among 141,743 observations according to data from six authors.

with CABG, optimal medical therapy (OMT) was associated with a lower risk of death (OR = 0.84; 95% CI: 0.71–0.97).[30]

Meta-analysis of two coordinated randomized controlled trials (RCTs) examining the long-term four-year safety profile of the Stellarex drug-coated balloon (DCB) and percutaneous transluminal angioplasty (PTA) for the treatment of peripheral arterial disease in 589 (419 DCB; 170 PTA) patients. The overall 4-year mortality rate was 81 (13.8%) of 589.[31]

According to the results of a five-year study of 300 patients with unprotected arterial stenosis using sirolimus-secreting stents, mortality was observed in 52 (17.3%).[32] The long-term mortality rate in patients who underwent CAS was n = 4415, with a 5-year mortality rate of 18.3%.[33] Mortality at 5 years, with an all-cause mortality rate of 12.0% in the FREEWAY drug-eluting balloon group versus 15.0% in the PTA group without paclitaxel.[34]

Evidence presented in 5 publications for 1972-2020 with the participation of 82 869 patients indicate that after stenting during follow-up periods of up to 4-5 years, mortality varies significantly, ranging from 0.84% to 18.3%, with an average of 2 % (1635 died).

3.6 Mortality after stenting during follow-up up to 6 years

Percutaneous coronary intervention was performed in 158 patients; during a follow-up period of 54±25 months, 24 (15%) deaths were recorded.[35] In PCI 4134, the mortality rate was 48 (1.17%).[36] As a result, according to two studies, of 4,292 patients operated on, 1.7 % (72) death occurred within the specified time frame.

3.5 Mortality after stenting during follow-up periods of up to 4-5 years

Mortality rates after stenting during follow-up periods of up to 4–5 years tend to decrease. At 5 years after left coronary artery stenting in 1,607 patients (bifurcation lesions: n = 1318 and nonbifurcation lesions: n = 289), all-cause mortality ranged from 0.87 to 1.71, p = 0.2622.[29]

Ninety-seven studies were analyzed, covering 75,754 patients, with a mean follow-up of 42.5 months. Compared

3.7 Mortality after stenting during follow-up periods of up to 7-10 years

Taken together, these studies at follow-up periods of up to 7-10 years confirm the results that an increase in the number of deaths is determined. Among 3917 patients operated on for angioplasty with stenting, mortality was 1.1% (43 died).[37] and in a group of 252 patients it was in 31.1% (78).[38] In drug-eluting stenting (DES) over bare metal stents (BMS) 7 years after stenting of the unprotected left main coronary artery (LMCA), mortality among 182 patients was 11%.[39]

In a randomized controlled trial (RCT) of 4595 patients undergoing PCI with drug-eluting stents, the cumulative 10-year all-cause mortality rate after PCI was 12.0%.[40] A number of investigators have shown that PCI with extended stenting (TSL >100 mm) was associated with higher all-cause mortality at 10 years compared with PCI with non-extended stenting or CABG (32.3%, 26.2%, and 23. 8% respectively).

When counting stents dichotomously, 10-year all-cause mortality was 31.4% and 26.7% in patients with >5 stents (n=300) and ≤5 stents (n=593), respectively, and the total

number of stents implanted was also is associated with worse outcome.[41] In patients who underwent revascularization after myocardial infarction with significant LCA, of 1102 patients who underwent stenting, the 10-year mortality rate was 24.7%. Stent thrombosis (ST) is a serious complication of PCI that can cause myocardial infarction in 60–70% of cases and increase the risk of mortality by 20–25%.[42]

Five RCTs involving a total of 4499 patients were included in the final analysis. Median follow-up was 96 months. The risks of all-cause mortality [HR 1.09 (95% CI 0.88–1.34)] and cardiovascular mortality [1.14 (0.88–1.47)] were comparable between PCI and CABG.[43]

A study of the effectiveness of various polymer coating strategies for new generation drug-eluting stents (DES) among 4953 patients found no calcification in 24.5%, mild, moderate or severe coronary artery calcification was observed in 41.8%, 25.8% and 8.0 % of patients respectively. At 10-year follow-up, all-cause mortality was 25.3% in the group without arterial calcification, 32.1% in the mild group, 41.7% in the moderate group, and 46.5% in the severe group.[44] Ten years after the index PCI, 3 of 4 study patients (2037/2705 patients (75.3%)) were still alive. Overall, 668/2705 (24.7%) patients had died: 88/212 (41.5%) patients with underlying peripheral arterial disease (PAD) and 580/2493 (23.1%) patients without PAD.[45]

The evidence presented in this section suggests that in the long-term follow-up period, mortality after PCI was 4 264 (18,5%) among 23 098 patients and is significantly higher than the average rates compared with previous follow-up periods.

4. Conclusion and prospects

The results of a systematic review of 41 sources from 277,388 publications covering a 24-year period from 1998 to 2024 indicate that mortality after stenting is poorly understood and varies significantly. According to 479,695 observations after arterial stenting, the mortality rate was 4.7% (22,437 people died) and ranged from 0.59% to 46.5%. A pooled analysis revealed three most significant increases in mortality - within 30 days (2.4%), at the third year (10.2%), and after 7-10 years (18.5%) (Table 2, Figs. 5,6,7). It is well known that arterial stenting and coronary artery bypass grafting are essentially

Table 2: Mortality rates after stenting.

Terms of observation	Publication number	Researched articles in these publications	Publication periods	Number of observations	Mortality	
					Absolute number	%
30 days	4	98	1982-2020	1784	43	2,4
year	11	312	1971-2023	113785	1436	1,2
2 years	3	69	1994-2020	112124	493	0,4
3 years	6	114	1997-2019	141743	14494	10,2
4-5 years	6	162	1972-2020	82869	1635	2
6 years	2	49	1993-2021	4292	72	1,7
7-10 years	9	353	1978-2022	23098	4264	18,5
Total:	41	1157	1971-2024	479695	22437	4,7

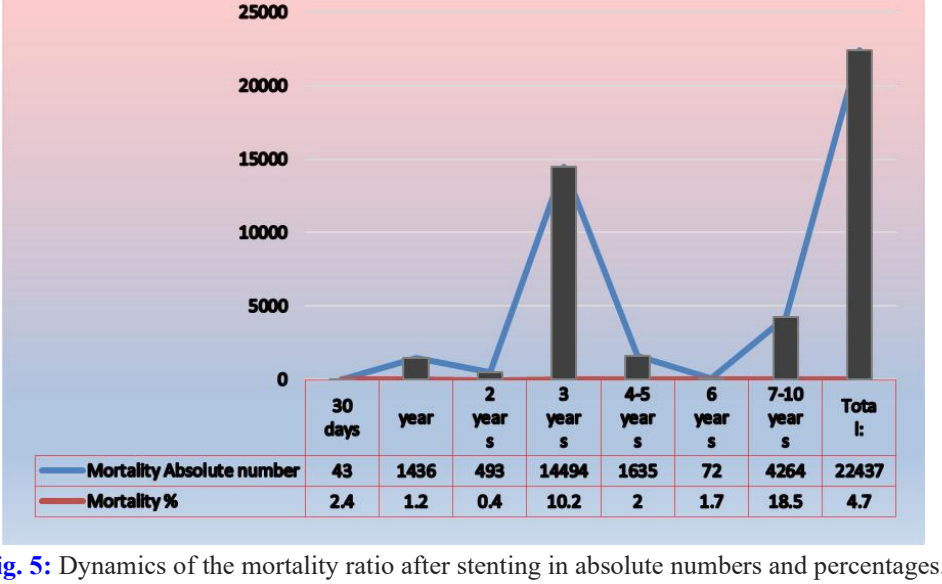

Fig. 5: Dynamics of the mortality ratio after stenting in absolute numbers and percentages.

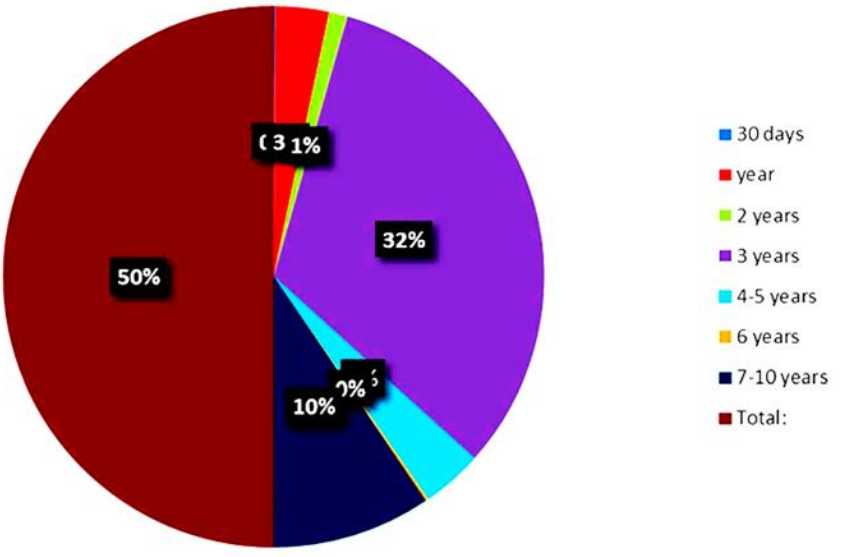

Fig. 6: Proportion of deaths after stenting.

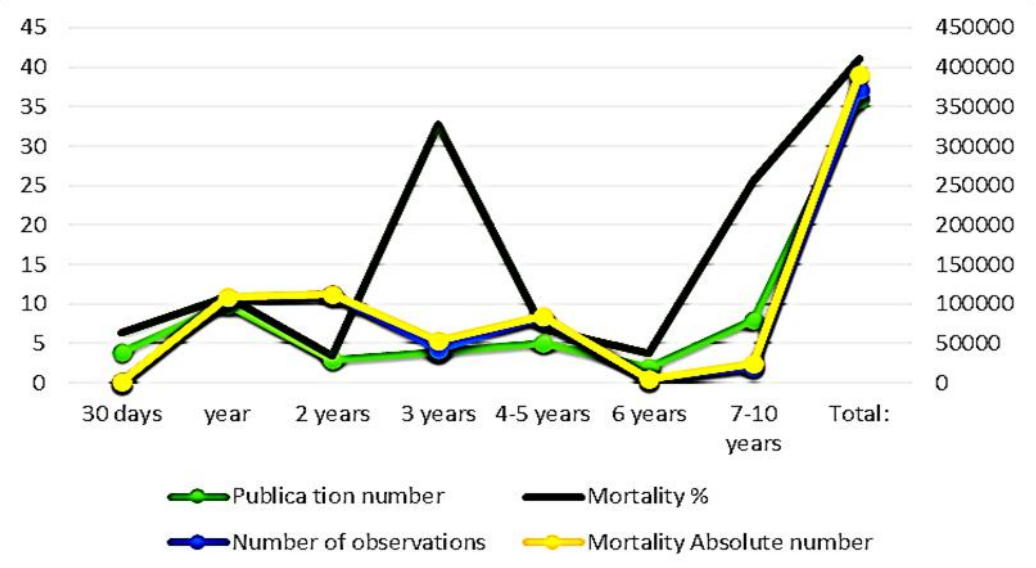

Fig. 7: Number of publications, number of observations, mortality in absolute numbers, as a percentage after stenting by year.

palliative angioplasty methods - atherosclerotic plaques are not removed. Unfortunately, the publications do not consider or disclose the role of a stent in an artery as a "foreign body" and, therefore, as a cause of death. Therefore, the development of methods for removing atherosclerotic plaques from the lumen of an artery is a primary and strategic task of scientific and clinical medicine. We have developed innovative endovascular technologies for the prevention and treatment of arterial atherosclerosis and received patents for: "Device and method for restoring the patency of arterial vessels" and "Device for selective ultrasound dissection of atherosclerotic plaques and a method for restoring the patency of arterial vessels".[46,47,48,49] The device allows for radical and complete destruction (dissolution) and removal of atherosclerotic plaques from the lumen of an artery, restoring normal blood flow, surpassing modern stents in seven key indicators. It is expected that planned preventive removal of atheroma from the artery in people over 40 years of age, covering about 1.5 billion people annually, will increase the average life expectancy by 15 years or more. It is predicted that mortality, disability, ability to work, quality of life, comfortable longevity, as well as improvement of the demographic indicators of the population and a decrease in the burden on health care resources will be reduced.

Taken together, the results of the study of mortality statistics for patients after angioplasty provide valuable information on the effectiveness and safety of the procedure and allow us to assess its significance and develop the most optimal tactics and methods of treatment.

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Conflict of Interest
There are no known competing financial interests or personal relationships that could affect the work described in this article.

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References
[1] World Health Organization, *Cardiovascular diseases (CVDs)*, World Health Organization, 2024, https://www.who.int/ru/health-topics/cardiovascular-diseases#tab=tab_1.
[2] Precedence Research, Coronary Stents Market Size, Share and Trends 2025 to 2034, Toronto: Precedence Research, 2025, URL: https://www.precedenceresearch.com/coronary-stents-m
[3] https://www.gminsights.com/ru/industry-analysis/stent-market.
[4] https://www.globaldata.com/store/report/coronary-stents-devices-market-analysis/.
[5] Precedence Research, Coronary stents market size, share, growth, trends, report 2024 to 2032, 2024, https://www.precedenceresearch.com/coronary-stents-market.
[6] Moriel M, Feld S, Almagor Y, Balkin JA, Klutstein MW, Meerkin D, Rosenmann D, Winkler H, Tzivoni D. Results of coronary artery stenting in women versus men: a single center experience, *Israel Medical Association Journal*, 2003, **5**(6), 398-402,
[7] F. Alfonso, Left main coronary artery stenting, *Journal of the American College of Cardiology*, 2009, **53**, 1769-1772, doi: 10.1016/j.jacc.2009.02.017.
[8] Li XW, Liu Y, Gao MD, Xiao JY, Gao J. Long-term outcomes of 316 patients with STEMI following coronary stent implantation, *American Journal of Translational Research*, 2022, **14**(6), 4139-4145.
[9] M. S. Chauhan, R. E. Kuntz, K. K. L. Ho, D. J. Cohen, J. J. Popma, J. P. Carrozza Jr, D. S. Baim, D. E. Cutlip, Coronary artery stenting in the aged, *Journal of the American College of Cardiology*, 2001, **37**, 856-862, doi: 10.1016/s0735-1097(00)01170-0.
[10] J. De Gregorio, Y. Kobayashi, R. Albiero, B. Reimers, C. Di Mario, L. Finci, A. Colombo, Coronary artery stenting in the elderly: short-term outcome and long-term angiographic and clinical follow-up, *Journal of the American College of Cardiology*, 1998, **32**, 577-583, doi: 10.1016/s0735-1097(98)00287-3.
[11] A. Black, R. Cortina, I. Bossi, R. Choussat, J. Fajadet, J. Marco, Unprotected left main coronary artery stenting - Correlates of midterm survival and impact of patient selection, *Journal of the American College of Cardiology*, 2001, **37**, 832-838, doi: 10.1016/S0735-1097(00)01176-1.
[12] Puymirat E, Labèque JN, Coste P. Angioplastie du tronc gauche non protégé: évolutions immédiates et à moyen terme de 24 procédures Unprotected left main coronary artery stenting: immediate and medium-term outcomes of 24 procedures, *Annales de Cardiologie et d'Angéiologie,* 2008, **57**(4), 195-200, doi: 10.1016/j.ancard.2008.05.001.
[13] Sukiennik A, Ostrowska-Nowak J, Wiśniewska-Szmyt J, Radomski M, Rychter M, Jabłoński M, Białoszyński T, Koziński M, Fabiszak T, Dobosiewicz R, Zabielska E, Sukiennik T, Kubica A, Król A, Demidowicz K, Chojnicki M, Grabczewska Z, Swiatkiewicz I, Bogdan M, Grześk G, Kubica J. Predicted and observed in-hospital mortality after left main coronary artery stenting in 204 patients, *Cardiology Journal*, 2008, **15**(3), 268-76.
[14] L. Ali, S. Malik, A. B. Khalid, M. Sultan, N. Sadiq, Safety and technical success of percutaneous left main coronary artery stenting, *Pakistan Journal of Medical Sciences*, 2014, **30**(4), 735-738, doi: 10.12669/pjms.304.4859
[15] M. Cimci, J. Polad, M. Mamas, A. Iniguez-Romo, B. Chevalier, R. Abhaichand, A. Aminian, A. Roguin, G. Maluenda, M. Angioi, G. Cassel, S. Kuramitsu, L. Jacobs, R. Debrus, F. Malik, D. Hildick-Smith, P. Laanmets, M. Roffi, Outcomes and regional differences in practice in a worldwide coronary stent registry, *Heart*, 2022, **108**, 1310-1318, doi: 10.1136/heartjnl-2021-320116.
[16] M. Silvestri, P. Barragan, J. Sainsous, G. Bayet, J.-B. Simeoni, P.-O. Roquebert, G. Macaluso, J.-L. Bouvier, B. Comet, Unprotected left main coronary artery stenting: immediate and medium- term outcomes of 140 elective procedures, *Journal of the American College of Cardiology*, 2000, **35**, 1543-1550, doi: 10.1016/s0735-1097(00)00588-x.
[17] H. Wang, X. Xie, Q. Zu, M. Lu, R. Chen, Z. Yang, Y. Gao, One-year outcomes of polymer-free amphilimus-eluting stents versus durable polymer zotarolimus-eluting stents in patients with diabetes mellitus: a meta-analysis, *Cardiovascular Diabetology*, 2022, **21**, 220, doi: 10.1186/s12933-022-01673-8.
[18] W. J. Skorupski, M. Kałużna-Oleksy, M. Lesiak, A. Araszkiewicz, W. Skorupski, S. Grajek, P. Mitkowski, M. Pyda, M. Grygier, Short- and long-term outcomes of left main coronary artery stenting in patients disqualified from coronary artery

bypass graft surgery, *Journal of Personalized Medicine*, 2022, **12**, 348, doi: 10.3390/jpm12030348.

[19] J. Zhu, A. Rao, K. Berger, M. Gopal, A. Vrudhula, D. Han, A. Vouyouka, W. Ting, D. Finlay, S. Y. Kim, R. Tadros, M. Marin, P. Faries, Determinants of mortality and mid-term outcomes after transcarotid artery revascularization and transfemoral carotid artery stenting, *Journal of Endovascular Therapy*, 2025, **32**, 2082-2093, doi: 10.1177/15266028241235791.

[20] D. Georges, D. Kreft, G. Doblhammer, Retraction: coronary artery bypass grafting *vs*. drug-eluting stent implantation: the probabilities of reintervention, transition to severe care-need, nursing home, and death in patients with coronary artery disease within the first three years: evaluations based on health claims data in Germany, *Journal of Thoracic Disease*, 2025, **17**, 522-523, doi: 10.21037/jtd-24-251.

[21] V. A. Voudris, J. S. Skoularigis, J. S. Malakos, G. C. Kourgianides, G. S. Pavlides, A. N. Manginas, G. D. Kolovou, D. V. Cokkinos, Long-term clinical outcome of coronary artery stenting in elderly patients, *Coronary Artery Disease*, 2002, **13**, 323-329, doi: 10.1097/00019501-200209000-00004.

[22] J. Al Suwaidi, D. R. Holmes Jr, A. M. Salam, R. Lennon, P. B. Berger, Impact of coronary artery stents on mortality and nonfatal myocardial infarction: meta-analysis of randomized trials comparing a strategy of routine stenting with that of balloon angioplasty, *American Heart Journal*, 2004, **147**, 815-822, doi: 10.1016/j.ahj.2003.11.025.

[23] E. Cerrato, M. Pavani, U. Barbero, F. Colombo, A. Mangieri, N. Ryan, G. Quadri, F. Tomassini, D. G. Presutti, S. Calcagno, A. Franzè, B. Bellini, F. D'Ascenzo, A. Ielasi, M. De Benedictis, L. Azzalini, M. Mancone, J. Escaned, M. Montorfano, A. Latib, F. Varbella, Incidence, management, immediate and long-term outcome of guidewire and device related grade III coronary perforations (from G3CAP - cardiogroup VI registry), *The American Journal of Cardiology*, 2021, **143**, 37-45, doi: 10.1016/j.amjcard.2020.12.041.

[24] T. A. Batyraliev, D. V. Fettser, Z. Karben, B. A. Sidorenko, Stenting of unprotected left main coronary artery: complications during 3 years follow up, *Kardiologiia*, 2009, **49**(2), 22-6.

[25] Q. Wang, Q. Tan, D. Liu, H.-M. Yang, L. Ma, Clinical outcomes of transradial unprotected left main coronary artery stenting in the elderly, *Saudi Medical Journal*, 2014, **35**(8), 838-42.

[26] S. Nestler, D. Kreft, P. Donndorf, H. Ince, G. Doblhammer, Stents versus bypass surgery: 3-year mortality risk of patients with coronary interventions aged 50+ in Germany, *Journal of Cardiothoracic Surgery*, 2022, **17**, 246, doi: 10.1186/s13019-022-02014-2.

[27] F. Philip, S. Stewart, J. A. Southard, Very late stent thrombosis with second generation drug eluting stents compared to bare metal stents: Network meta-analysis of randomized primary percutaneous coronary intervention trials, *Catheterization and Cardiovascular Interventions*, 2016, **88**, 38-48, doi: 10.1002/ccd.26458.

[28] F. Moroni, M. Seth, H. U. Changezi, M. Karve, D. S. Arora, M. Sharma, E. Pielsticker, A. D. Berman, D. Lee, M. I. Qureshi, L. Azzalini, D. Sukul, H. S. Gurm, Cause and preventability of in-hospital mortality after PCI: a statewide root-cause analysis of 1, 163 deaths, *PLoS One*, 2024, **19**, e0297596, doi: 10.1371/journal.pone.0297596.

[29] M. Ohya, K. Kadota, M. Toyofuku, T. Morimoto, H. Higami, Y. Fuku, K. Yamaji, H. Muranishi, Y. Yamaji, K. Nishida, D. Furukawa, T. Tada, E. Ko, K. Ando, H. Sakamoto, T. Tamura, K. Kawai, T. Kimura, Long-term outcomes after stent implantation for left main coronary artery (from the multicenter assessing optimal percutaneous coronary intervention for left main coronary artery stenting registry), *The American Journal of Cardiology*, 2017, **119**, 355-364, doi: 10.1016/j.amjcard.2016.10.033.

[30] N. Taglieri, A. G. Bruno, G. Ghetti, C. Marrozzini, F. Saia, N. Galié, T. Palmerini, Target lesion failure with current drug-eluting stents, *JACC: Cardiovascular Interventions*, 2020, **13**, 2868-2878, doi: 10.1016/j.jcin.2020.09.014.

[31] S. P. Lyden, M. Brodmann, S. A. Parikh, P. Krishnan, H. Schroeder, M. Werner, A. Holden, K. Ouriel, T. Tarra, W. A. Gray, Four-year patient-level pooled mortality analysis of the ILLUMENATE US Pivotal and EU randomized controlled trials, *Journal of Vascular Surgery*, 2022, **75**, 600-607, doi: 10.1016/j.jvs.2021.07.244.

[32] Y. Velibey, T. S. Guvenc, A. T. Alper, Very long-term follow-up for left main coronary artery stenting: a missing piece of the jigsaw puzzle, *Journal of Thoracic Disease*, 2016, **8**, 2353-2356, doi: 10.21037/jtd.2016.08.67.

[33] J. A. Columbo, P. Martinez-Camblor, T. A. MacKenzie, R. Kang, S. W. Trooboff, P. P. Goodney, A. J. O'Malley, A comparative analysis of long-term mortality after carotid endarterectomy and carotid stenting, *Journal of Vascular Surgery*, 2019, **69**, 104-109, doi: 10.1016/j.jvs.2018.03.432.

[34] K. Hausegger, W. Kurre, H. Schröder, J. Dambach, S. Stahnke, C. Loewe, K. Schürmann, R. Fischbach, J. Textor, S. Schäfer, S. Müller-Hülsbeck, Long-term follow-up and mortality rate of patients of the randomized freeway stent study, *CardioVascular and Interventional Radiology*, 2024, **47**, 186-193, doi: 10.1007/s00270-023-03646-0.

[35] M. Ali, A. Hanley, B. McAdam, R. O'Hanlon, T. Gumbrielle, R. Sheahan, D. P. Foley, Long-term clinical outcomes after unprotected left main coronary artery stenting in an all-comers patient population, *Catheterization and Cardiovascular Interventions*, 2013, **82**, E411-E418, doi: 10.1002/ccd.24861.

[36] M. Gaudino, I. Hameed, A. Di Franco, A. Naik, M. Demetres, G. Biondi-Zoccai, S. Bangalore, Comparison of SYNTAX score strata effects of percutaneous and surgical revascularization trials: a meta-analysis, *The Journal of Thoracic and Cardiovascular Surgery*, 2023, **165**, 1405-1413.e13, doi: 10.1016/j.jtcvs.2021.05.036.

[37] S. Kohsaka, M. Goto, S. Virani, V.-V. Lee, N. Aoki, M. A. Elayda, R. M. Reul, J. M. Wilson, Long-term clinical outcome of coronary artery stenting or coronary artery bypass grafting in patients with multiple-vessel disease, *The Journal of Thoracic and Cardiovascular Surgery*, 2008, **136**, 500-506, doi: 10.1016/j.jtcvs.2007.11.050.

[38] P. E. Buszman, P. P. Buszman, R. S. Kiesz, A. Bochenek, B. Trela, M. Konkolewska, D. Wallace-Bradley, M. Wilczyński, I. Banasiewicz-Szkróbka, E. Peszek-Przybyla, M. Krol, M. Kondys, K. Milewski, S. Wiernek, M. Dębiński, A. Żurakowski, J. L. Martin, M. Tendera, Early and long-term results of unprotected left main coronary artery stenting, *Journal of the American College of Cardiology*, 2009, **54**, 1500-1511, doi: 10.1016/j.jacc.2009.07.007.

[39] S. Kubo, K. Kadota, T. Shimada, M. Ozaki, T. Ichinohe, H. Eguchi, K. Miyake, Y. Hyodo, N. Saito, H. Otsuji, S. Otsuru, D. Hasegawa, Y. Shigemoto, S. Habara, T. Tada, H. Tanaka, Y. Fuku, H. Katoh, H. Yamamoto, S. Fujii, T. Goto, K. Mitsudo, Seven-year clinical outcomes of unprotected left main coronary artery stenting with drug-eluting stent and bare-metal stent, *Circulation Journal*, 2013, **77**, 2497-2504, doi: 10.1253/circj.cj-13-0032.

[40] N. W. S. Chew, C.-H. Ng, G. Kong, K.-S. Lee, D. J. H. Tan, O. Z. Lim, Y. H. Chin, B. C. Tai, T. Gu, S.-J. Park, D.-W. Park, M.-C. Morice, T. Kofidis, J. W. L. Yip, P.-H. Loh, K.-H. Chan, A. F. Low, C.-H. Lee, T.-C. Yeo, H.-C. Tan, M. Y. Chan, Meta-analysis of percutaneous coronary intervention versus coronary artery bypass grafting for left main narrowing, *The American Journal of Cardiology*, 2022, **173**, 39-47, doi: 10.1016/j.amjcard.2022.02.044.

[41] H. Hara, M. Ono, H. Kawashima, N. Kogame, M. J. Mack, D. R. Holmes, M.-C. Morice, P. M. Davierwala, F. W. Mohr, D. J. F. M. Thuijs, S. J. Head, A. P. Kappetein, Y. Onuma, P. W. Serruys, for the SYNTAX Extended Survival Investigators, Impact of stent length and diameter on 10-year mortality in the SYNTAXES trial, *Catheterization and Cardiovascular Interventions*, 2021, **98**, E379-E387, doi: 10.1002/ccd.29721.

[42] I. Hetherington, H. Totary-Jain, Anti-atherosclerotic therapies: Milestones, challenges, and emerging innovations, *Molecular Therapy*, 2022, **30**, 3106-3117, doi: 10.1016/j.ymthe.2022.08.024.

[43] A. Garg, A. Rout, H. Raheja, H. Hakeem, S. Sharma, Long-term follow-up of percutaneous coronary intervention versus coronary artery bypass grafting in left main coronary artery disease: a systematic review and meta-analysis, *Catheterization and Cardiovascular Interventions*, 2021, **98**, 427-433, doi: 10.1002/ccd.29338.

[44] T. Rheude, T. Koch, M. Joner, T. Lenz, E. Xhepa, J. Wiebe, J. J. Coughlan, A. Aytekin, S. Cassese, K.-L. Laugwitz, H. Schunkert, A. Kastrati, S. Kufner, Ten-year clinical outcomes of drug-eluting stents with different polymer coating strategies by degree of coronary calcification: a pooled analysis of the ISAR-TEST 4 and 5 randomised trials, *EuroIntervention*, 2023, **18**, 1188-1196, doi: 10.4244/eij-d-22-00781.

[45] T. H. Pinxterhuis, E. H. Ploumen, D. van Vliet, K. Gert van Houwelingen, M. G. Stoel, F. H. de Man, M. Hartmann, P. Zocca, G. C. Linssen, R. H. Geelkerken, C. J. Doggen, C. von Birgelen, Ten-year mortality after treating obstructive coronary atherosclerosis with contemporary stents in patients with or without concomitant peripheral arterial disease, *Atherosclerosis*, 2024, **392**, 117488, doi: 10.1016/j.atherosclerosis.2024.117488.

[46] Darmenov O. Patent No. 33009" RK "Device and method for restoring the patency of arterial vessels". Industrial property. Official Bulletin, Kazakhstan, 2018, 30, 2, from 47 to 48. https://ebulletin.kazpatent.kz/invention/details/89496.

[47] Darmenov O. Patent No. 033508. Device and method for restoring the patency of arterial vessels. EAPO Bulletin "Inventions (Eurasian applications and patents)" Bulletin 10´2019, Russia, 10, 8, https://old.eapo.org/ru/publications/bulletin/ea201910/HTML/033508.html.

[48] Darmenov O. Patent No. 33436 Device for selective ultrasound dissection of atherosclerotic plaques and a method for restoring the patency of arterial vessels. / Electronic Bulletin 6', 2019, RSE "National Institute of Intellectual Property", https://ebulletin.kazpatent.kz/invention/details/89496.

[49] Darmenov O. Patent No. 033442 Device for selective ultrasound dissection of atherosclerotic plaques and a method for restoring the patency of arterial vessels / Derwent Innovations Index (Web of Science, Clarivate Analytics): 2019-A7511C EAPO Bulletin "Inventions (Eurasian Applications and Patents)" Bulletin 10', 2019, https://www.eapo.org/services/?url=https%3A%2F%2Fold.eapo.org%2Fru%2Fpatents%2Freestr%2Fpatent.php%3Fid%3D33442.

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