Coronary stent infection; a systematic review

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Coronary stent infection: a systematic review

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Coronary stent infection (CSI) is the rarest complication associated with the percutaneous coronary intervention, occurring in less than 0.1% of cases. So far, all reported instances are limited to case reports. CSI presents itself in various, often confusing, ways in clinical settings. Therefore, the current systematic review summarizes reports of CSI's clinical presentations, causative pathogens, diagnoses and treatments. This systematic review considered three online databases, using reference lists as an additional source. All case reports or case series with stent infection in the coronary artery were included – however, reviews or commentaries, articles not published in English, and articles mentioning a history of hemodialysis or any surgery were excluded. Thirty-two studies on 34 CSI patients were included in the final qualitative analysis. CSI predominantly affected males of a wide range of ages. The most common symptoms were chest pain and fever with various onsets. Interestingly, CSI usually occurred during the first stent implantation. Cultures and coronary angiography were the most common methods used to diagnose CSI. Furthermore, drug-eluting stents had a higher risk of infection than bare-metal stents. Aneurysms were the most frequent abnormalities observed in infected stents. The bacteria that most often caused CSI were *Staphylococcus aureus* and *Pseudomonas aeroginosa*. More than 90% of the reports mentioned using various antibiotics, and 74% mentioned carrying out surgery. Finally, a mortality rate of 26.47% among CSI patients was calculated. *Coron Artery Dis* XXX: 000–000 Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

Coronary artery disease (CAD) is a major global health problem, as an estimated 126 million individuals worldwide are reported to suffer from CAD. In addition, CAD was responsible for 9 million deaths in 2017 [1]. Percutaneous coronary intervention (PCI) is well-recognized as a transformative CAD treatment first performed (balloon angioplasty) in 1977 by Andreas Grüntzig [2]. Since then, many advanced techniques and instruments have augmented this treatment, most notably the implantation of bare-metal stents (BMSs) to multiple generations of drug-eluting stents (DESs).

Complications rarely arise during PCI but are life-threatening when they occur. Complications such as the no-reflow phenomenon and stent thrombosis occur in about 2% of cases, while coronary stent infection (CSI) occurs in less than 0.1% of cases (all such instances are limited to case reports) [3]. The first report of a CSI case described a Palmaz-Schatz-stent infection in a 66-year-old woman in 1993 [4]. The patient died despite undergoing emergency cardiac surgery. A previous study that reviewed 23 cases demonstrated that the mortality rate of CSI was 39% [5]. Moreover, CSI has various clinical presentations that are often confusing. Therefore, this study systematically reviews the clinical presentation, causative pathogens, diagnoses and treatments associated with reported CSI cases.

Materials and methods

Study design

We performed this systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This systematic review is registered in the university hospital medical information network (UMIN) with registration number UMIN000043308.

Literature search

A literature search was conducted on three online databases (PubMed, ScienceDirect and ProQuest) using the keywords 'coronary stent infection' and 'stent infection.' The reference lists of both included and excluded studies were also screened for additional relevant studies.

Inclusion and exclusion criteria

Relevant full-text articles were assessed on the basis of the inclusion and exclusion criteria. Specifically, case reports or case series with stent infection in the coronary artery were included, while (1) reviews or commentaries,

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(2) articles not published in English and (3) articles mentioning a history of hemodialysis or any surgery were excluded.

Data extraction and analysis

From the included articles, two independent reviewers directly extracted data regarding the authors, publication year, location, patient(s) demographics, initial presentation, onset after the procedure, involved vessel and any angiography abnormalities, type of stent, pathogen involved, treatment approaches and outcomes. The collected data are presented descriptively on the basis of baseline characteristics, clinical presentation, diagnostic methods, stent and vessel pathology, causative pathogens, management and outcomes.

Results

Selected studies and baseline characteristics

Initially, 571 articles were screened. Of these, 32 studies involving a total of 34 CSI patients were included in the analysis (Fig. 1). The earliest included case was reported by Leroy *et al.* (1996) in France [6]. Although the first-known CSI case was reported in 1993 by Günther *et al.*, this case was not included in the present review because the full-text article could not be accessed. Most cases were reported in India, and most patients were males (88.24%), with ages ranging from 38 to 86 years old (Table 1).

Clinical presentations

The clinical presentations of CSI vary among cases. Most cases reported fever (76.47%) and chest pain (52.94%) as primary symptoms, followed by shortness of breath (11.76%). Additionally, Zateyshchikov *et al*. [26] and Dalal *et al*. [29] reported cardiogenic shock and cardiac arrest, respectively, upon the admission of the CSI case.

The onset of symptoms usually occurred within the first week after stent implantation. The earliest onset of CSI occurred 1-day postprocedure, while the latest onset occurred around seven years after the procedure [23,26]. The number of stent implantation procedures performed on patients ranged from one to three. Interestingly, most CSI cases resulted from the first stent implantation (67.65%).

Diagnostic methods

Blood culture (79.41%) and coronary angiography (70.59%) were the most preferred diagnostic methods reported. Some cases in which stent or pericardial fluid evacuation were conducted also involved tissue or pericardial fluid culture to confirm pathogenic causes. Some reports also utilized a PET-CT scan and cardiac CT scan. In some instances, cardiac MRI and gallium SPECT were performed for CSI diagnosis. One postmortem study revealed coronary occlusion via an abscess [26]. Nineteen of 34 cases were definitively diagnosed by a surgical specimen or postmortem examination; the other 15 cases were confirmed by their fulfillment of Dieter's diagnostic criteria [38] (Table 2).

Stents and coronary abnormalities

DESs were the most commonly reported stents (67.65%), followed by BMSs (20.59%) and DES-BMS combination (5.88%). Two case reports did not specify the stent type. CSI occurred in the left anterior descending artery (LAD) in 21 cases and in the right coronary artery (RCA) in 14 cases. CSI in the left circumflex artery and left main coronary were rarely reported.

Twenty-nine reports describe abnormalities in coronary morphology, with aneurysm (true- and pseudoaneurysm) being the most common (64.71%), followed by vessel occlusion (32.35%) and in-stent restenosis (20.59%). Coronary-cameral fistula, coronary perforation and soft-tissue density collection were also reported.

Causative pathogens

All CSI pathogens identified in the current review were bacteria. *Staphylococci* bacteria were the most prevalent pathogens, of which *Staphylococcus aureus* was the most commonly reported. Out of 17 reports, seven cases included methicillin-resistant *Staphylococcus aureus*. *Pseudomonas aeroginosa* were also prevalent, while *Acinetobacter baumannii*, *Escherichia coli*, *Enterobacter cloacae*, and *Actinomyces oris* were reported in few cases. Bacterial cultures did not grow in two cases – these cases described a history of *Staphylococcus aureus* bacteremia 2 and 3 months before surgery, with one case traced back to rare gram-positive cocci [12,15].

Treatments, complications and outcome

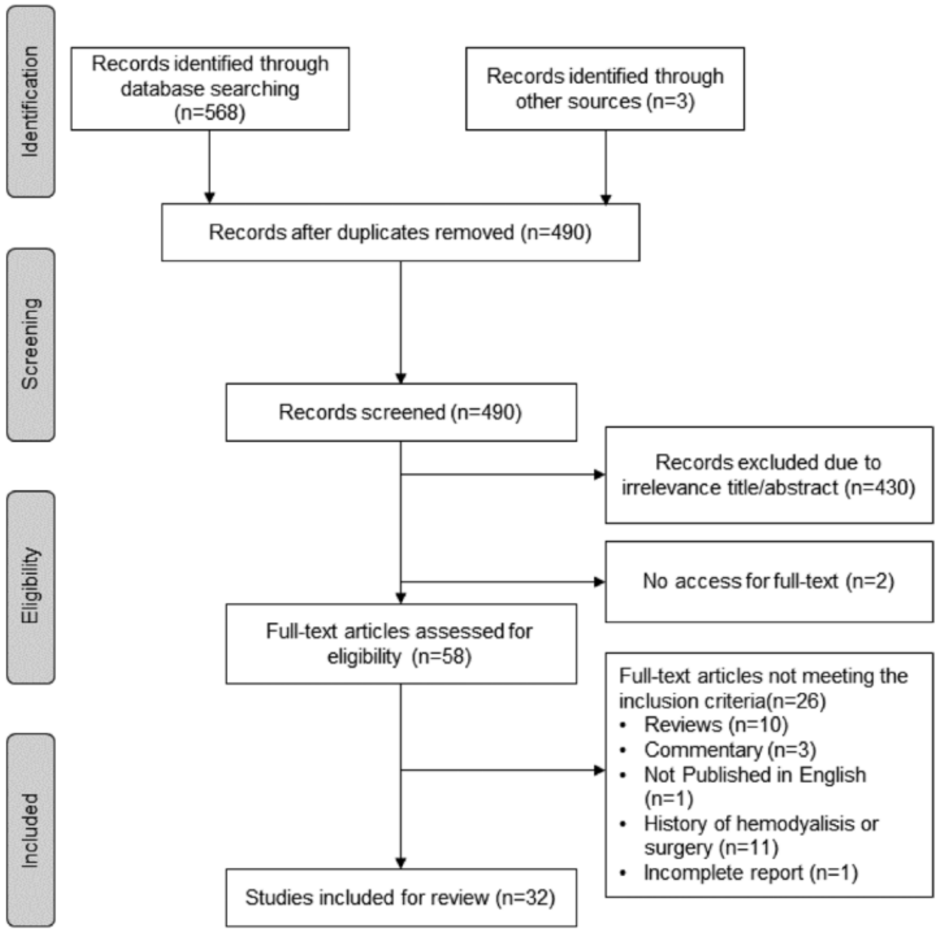
Antibiotic therapy was mentioned in 31 cases. One study did not mention giving any antibiotics, while another was a postmortem study. Meanwhile, surgery was performed in only 26 cases. Table 3 provides detailed information related to the antibiotics administered and the surgeries performed. Pericardial effusion, abscess, heart failure and valvular involvement were the most often reported complications. The results demonstrate a mortality rate of 26.47% among CSI patients.

Discussion

This systematic review addresses 34 CSI cases from 32 reports. CSI predominantly affected males of a wide range of ages. The most common symptoms were chest pain and fever, the onset of which varied among cases. Interestingly, most CSI cases occurred during the first stent implantation. Cultures and coronary angiography were the most common methods used to diagnose CSI, though some cases also reported more advanced imaging modalities.

The majority of infected stents were DESs placed in the LAD or RCA. Furthermore, aneurysms were the most common abnormalities found in infected stents, followed

Fig. 1



Systematic search and screen flowchart.

by vessel occlusion and in-stent restenosis. Pathogenic agents commonly caused bacteria, namely *Staphylococcus aureus* and *Pseudomonas aeroginosa*. Hence, more than 90% of the cases mentioned using various antibiotics, while 74% of the cases involved surgery. In addition, our systematic review presented a mortality rate of 26.47% among CSI patients.

Our findings are similar to a previous review of 25 coronary infection cases carried out by Franco *et al.* [5]. Their review included patients with balloon-related and saphenous vein graft stent infections and showed that the most common symptoms were fever, chills and chest pain. These symptoms occurred two days to 4 months post-intervention.

In addition, coronary angiography was the most preferred diagnostic modality. The prevalence of infection in DESs was slightly higher than in BMSs (48% vs. 32%), and the most common causative pathogens were *Staphylococcus aureus* (80%) and *Pseudomonas aeroginosa* (20%). Surprisingly, the recorded CSI mortality rate was 39% after excluding balloon-related infections. Another review of 17 cases demonstrated similar results but did not address the type of stents used [39].

The pathophysiology of CSI remains unclear. Stent implantation, specifically as it relates to its struts, disrupts coronary endothelial surface and impairs the host defense mechanism. The stent itself serves as an ideal reservoir for bacterial growth [5]. Moreover, increasing the popularity and use of DESs is associated with a higher incidence of CSI. The immunosuppressive effect of eluted drugs inhibits restenosis via neointima growth and hyperplasia suppression while also reducing the protective function of neointima against infection [40].

Table 1 Summary of coronary stent infection cases

Author	Sex	Age	Presenting Symptoms	First onset	*N* of PCI	Diagnostic methods	Stent type	Vessel	Angiographic abnormality	Pathogen	Complication	Outcome
Leroy *et al.* France (1996) [6]	M	49	F	1 week	1	BC, CAG, TC, Urine Culture	BMS	LAD	Saccular aneurysm	*P. aeroginosa*	VI, IE	Died
Bouchart *et al.* France (1997) [7]	M	38	CP	6 days	1	BC, CTC, TC	BMS	LCX	Pseudoaneurysm, VO	*P. aeroginosa*	PE, partial aneurysm rupture	Survived
Grewe *et al.* Germany (1999) [8]	M	54	CP, F	4 days	1	BC, TC, Autopsy	BMS	LAD	-	*S. aureus*	VF, HF, suppurative pancarditis	Died
Liu *et al.* USA (2003) [9]	M	72	CP, F	18 days	1	BC, CAG, TC	BMS	LAD	Pseudoaneurysm	*S. aureus, S. simulans, S. capitis*	Abscess	Survived
Hoffman *et al.* Israel (2005) [10]	M	80	CP, F	1 week	1	BC, CTC	DES	LAD	Soft-tissue mass	*S. aureus*	Lung and Liver Abscess, Bacterial Endophthalmitis	Survived
Alfonso *et al.* Spain (2005) [11]	M	47	CP, F	2 days	2	BC, PFC	DES	RCA	-	*S. aureus*	PE, Hemopericardium	Died
Marcu *et al.* USA (2005) [12]	M	55	F	3 months	1	BC, CAG, Tissue Gram Staining	DES	LAD	Pseudoaneurysm ISR	History of *S. aureus,* Rare Gram-positive cocci	Granulation	Survived
Singh *et al.* India (2005) [13]	M	56	F, SoB	4 days	1	BC, CAG	DES, BMS	LAD, RCA	Saccular aneurysm, ISR	*S. aureus*	-	Survived
Garg *et al.* USA (2007) [14]	Fm	86	CP	>9 days	1	BC, CAG	DES	LAD, RCA	Mycotic aneurysm, Coronary perforation	MRSA	PE	Died
Kishida *et al.* Japan (2007) [15]	M	70	F	2 months	2	CAG, TC, CTC	DES	RCA	VO, aneurysm-fistula	no growth, history of *S. aureus* bacterimia	Microabscess	Survived
Schoenkerman and Lundstrom, USA (2009) [16]	M	59	F	4 days	1	BC, CAG, Urine Culture	BMS	LAD	Mycotic aneurysm	*S. aureus*	Aneurysm rupture, HFrEF, Shock, Lung Edema	Died
Lim *et al.* Singapore (2011) [17]	M	69	F	4 days	2	BC, CAG, CTC	DES	LAD	Pseudoaneurysm	MRSA	Low Cardiac Output Syndrome	Died
Furtado *et al.* India (2011) [18]	M	62	CP, F	2 weeks	1	BC, CAG, TC	DES	LAD	Pseudoaneurysm	*P. aeroginosa*	Abscess, PE	Survived
Patel *et al.* USA (2013) [19]	M	60	CP, SoB	8 weeks	1	PFC, CAG	DES	LAD	Mycotic aneurysm	MRSA	PE	Survived
Morris *et al.* UK (2013) [20]	Fm	ND	F	5 days	1	BC, Echo	ND	LM-LAD	-	*S. lugdunensis*	Abscess, PE	Died
Wedekind *et al.* Germany (2013) [21]	M	80	F	3 weeks	2	BC, PET-CT, PFC	DES	LAD, LCx	-	*E. coli*	PE	Survived
Chang *et al.* Taiwan (2014) [22]	M	38	CP	>1 year	>1	BC, CTC	ND	LM-LAD	Mycotic aneurysm	*S. aureus*	Multiorgan failure	Died
Satish *et al.* India (2015) [23]	ND	51	CP, F	2 days	1	BC, CAG	DES	LAD	Pseudoaneurysm	*Staphylococcus*	Abscess	Survived
Roubelakis *et al.* UK (2015) [24]	M	62	CP, F	3 years	1	BC, CAG, TC	DES	LAD	Aneurysm	*S. aureus*	Ruptured Aneurysm, PE	Survived
Sekhar *et al.* India (2015) [25]	M	60	F	15 days	1	BC, CAG, TC, FDG-PET-CT Scan	DES	RCA	ISR-VO	*P. aeroginosa, Enterobacter cloacae*	Abscess, VI, PE	Survived
Zateyshchikov *et al.* Russia (2015) [26]	M	45	Cardiac Shock	7 years	1	Autopsy	BMS	RCA	-	ND	Abscess-VO	Died
Madkaiker *et al.* India (2016) [27]	M	50	F	4 days	2	BC, CAG, TC	DES	LAD, LCx	Pseudoaneurysm, ISR	*P. aeroginosa*	HFrEF, Lung Edema	Survived
Aggarwal *et al.* India (2016) [28]	M	51	CP, F	>13 month	2	TC, CTC	DES	LAD	Pseudoaneurysm, VO	*Pseudomonas*	VI, HFrEF, non-sustained VT	Survived
Dalal *et al.* India (2017) [29]	Fm	66	CP	1 month	1	CAG, TC	DES	RCA	Aneurysm,VO	*P. aeroginosa*	Septic shock, AF, HFrEF,	Survived
	M	50	F, Cardiac Arrest	1 months	1	CAG, TC	DES	LCx	Aneurysm, VO	*P. aeroginosa* and *S. warneri*	HF	Survived

(continued)

Table 1 (continued)

Author	Sex	Age	Presenting Symptoms	First onset	*N* of PCI	Diagnostic methods	Stent type	Vessel	Angiographic abnormality	Pathogen	Complication	Outcome
Elder *et al.* Australia (2017) [30]	M	50	CP, F	2 days	2	BC, CAG, Galium-SPECT	DES, BMS	RCA	VO	MRSA	Pleural effusion, PE	Survived
Sangolkar *et al.* India (2018) [31]	M	66	F	3 years	2	BC, CAG, PET-CT	DES	RCA	Coronary-cameral fistula	*P. aeroginosa*	Abscess, VI, Sepsis, Lymphadenopathy	Survived
Shetty *et al.* India (2018) [32]	M	52	CP, F	9 months	1	BC, CAG, TC, CTC	DES	RCA	Aneurysm, VO	*Acinetobacter baumannii*, *Staphyloccocus aureus*	-	Survived
Shah *et al.* India (2018) [33]	M	53	F	2 years	1	TC, PET Scan, CMRI, Echo	DES	LAD	ISR	*P. aeroginosa*	Abscess, HFrEF	Survived
Sudhakar, India (2018) [34]	M	49	F, SoB	2 weeks	1	BC, CAG	DES	LAD	Fusiform Aneurysm, ISR	Suspect *P. aeroginosa*	VI, IE	Survived
Messaoud *et al.* Tunisia (2019) [35]	M	71	CP, F	12 days	1	BC, CAG, CTC	BMS	RCA	Mycotic aneurysm, ISR	*S. aureus*	RBBB, IE, VI, PE	Survived
Reddy *et al.* India (2019) [36]	M	50	CP, F, SoB	8 days	3	BC, CAG, TC, PFC	DES	LAD, RCA	Aneurysm, VO	MRSA	HFrEF, PE	Survived
	M	52	F	1 month	1	BC, CAG, TC, CTC, PET, PFC	DES	RCA	Pseudoaneurysm, VO	MRSA	AV block, HFrEF, PE, Granulation	Survived
Saeed *et al.* Qatar (2020) [37]	M	50	CP	3 months	2	BC, CAG, CMRI	DES	RCA	VO	*Actinomyces oris.*	Abscess	Survived

BC, blood culture; BMS, bare-metal stent; CAG, coronary angiography; CMRI, cardiovascular MRI; CP, chest pain; CTC, CT-Scan cardiac/coronary; DES, drug-eluting stent; F, fever; FDG, ^{18}F-fluorodeoxyglucose; Fm, female; HFrEF, heart failure reduced ejection fraction; IE, infective endocarditis; ISR, in-stent restenosis; M, male; MRSA, Methicillin-resistant *Staphylococcus aureus*; ND, no data; PE, pericardial efussion; PFC, pericardial fluid culture; SoB, shortness of breath; SPECT, single-photon emission computed tomography; TC, tissue culture; VI, valvular involvement; VO, vessel occlusion.

Aneurysms are commonly observed in CSI cases. Although the underlying mechanism is unknown, infected aneurysms are formed through arterial injury and direct infection – this is known as the 'two-hit' hypothesis [41]. The first hit strikes and the coronary artery wall, weakening it and leading to its degeneration. The first hit could be induced by atherosclerosis, trauma, coronary manipulation, infection or vascular inflammation. Subsequently, the second hit, which involves infectious materials, strikes the weakened arterial wall, thus facilitating rapid aneurysmal development.

Several methods have been utilized to diagnose CSI, with blood culture and coronary angiography being the most common. Nevertheless, previous reviews focus on the use of imaging modalities to diagnose CSI. These reviews agree that coronary angiography is the modality of choice for diagnosing CSI [5,39,40]. In the present review, we did not consider echocardiography as a diagnostic modality since it is primarily used to evaluate cardiac valve function, detect pericardial effusion, or rule out endocarditis. Additionally, transesophageal echocardiography is positive in only four out of 10 cases, whereas coronary angiography is positive in 10 out of 10 cases [39].

Currently, there is no universal standard for diagnosing CSI. However, Dieter proposed several criteria for diagnosing CSI cases [38]. A definitive diagnosis of CSI was on the basis of surgical specimens or postmortem examinations, revealing an infected coronary artery stent complex. Subsequently, three or more of the following conditions indicate CSI: (1) coronary stent implantation within the last 4 weeks, (2) repeated procedures through the same vascular sheath or complications at the puncture site, (3) bacteremia, (4) a fever above 101.5°F without any bacterial infection, (5) leukocytosis without any infection or acute coronary syndrome, (6) acute coronary syndrome, (7) cardiac imaging supporting the presence of persistent inflammation.

The classification of CSI has been proposed on the basis of its onset as adapted from orthopedic surgery [39]. Infections occurring within 10 days of stent implantation are classified as early-onset; otherwise, it is classified as late-onset.

Ideally, CSI should be treated with a combination of antibiotics and surgery. However, in some cases, treatments with antibiotics alone were effective [10,21,35]. Contrarily, several cases treated with antibiotics alone showed a different outcome [14,16,20]. Surgery is the logical treatment of choice for treating CSI, as surgery can provide a definitive diagnosis of CSI while also removing the infection source, repairing aneurysms, and providing bypass vascular grafts. However, patients often refuse surgery or die during surgery preparations [10,16].

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Table 2 Case diagnosis on the basis of previous criteria [38]

			Definitive Dx of CSI		Possible Dx of CSI							
Author	Sex	Age	Surgical specimen	Postmortem	1	2	3	4	5	6	7	Definitive/possible diagnosis
Leroy *et al.* France (1996) [6]	M	49	No growth	-	Yes	-	Yes	Yes	-	-	-	Possible
Bouchart *et al.* France (1997) [7]	M	38	Yes	-	Yes	-	Yes	Yes	-	-	Yes	Definite
Grewe *et al.* Germany (1999) [8]	M	54	-	Yes	Yes	-	Yes	Yes	-	Yes	-	Definite
Liu *et al.* USA (2003) [9]	M	72	Yes	-	Yes	-	Yes	Yes	Yes	-	-	Definite
Hoffman *et al.* Israel (2005) [10]	M	80	-	-	Yes	-	Yes	Yes	-	-	Yes	Possible
Alfonso *et al.* Spain (2005) [11]	M	47	-	-	Yes	-	Yes	Yes	-	-	Yes	Possible
Marcu *et al.* USA (2005) [12]	M	55	Yes	-	-	-	Yes	-	-	Yes	Yes	Definite
Singh *et al.* India (2005) [13]	M	56	-	-	Yes	-	Yes	Yes	-	Yes	-	Possible
Garg *et al.* USA (2007) [14]	Fm	86	-	-	Yes	-	Yes	-	-	Yes	Yes	Possible
Kishida *et al.* Japan (2007) [15]	M	70	Microabcess but no growth	-	-	-	Yes	Yes	-	Yes	Yes	Definite
Schoenkerman and Lundstrom, USA (2009) [16]	M	59	-	-	Yes	-	Yes	Yes	-	-	-	Possible
Lim *et al.* Singapore (2011) [17]	M	69	Massive pus was found but no culture was mentioned	-	Yes	-	Yes	Yes	-	Yes	Yes	Possible
Furtado *et al.* India (2011) [18]	M	62	Yes	-	Yes	-	Yes	Yes	Yes	-	Yes	Definite
Patel *et al.* USA (2013) [19]	M	60	-	-	-	-	History of MRSA bacteremia	-	-	Yes	Yes	Possible
Morris *et al.* UK (2013) [20]	Fm	ND	-	-	Yes	-	Yes	Yes	-	-	Yes	Possible
Wedekind *et al.* Germany (2013) [21]	M	80	Purulent pericardial fluid	-	Yes	-	Yes	Yes	-	-	Yes	Possible
Chang *et al.* Taiwan (2014) [22]	M	38	Yes	-	-	Several times but unspecified	Yes	-	-	Yes	Yes	Definite
Satish *et al.* India (2015) [23]	ND	51	Yes	-	Yes	-	Yes	Yes	-	-	-	Definite
Roubelakis *et al.* UK (2015) [24]	M	62	Yes	-	-	-	Yes	Yes	-	Yes	Yes	Definite
Sekhar *et al.* India (2015) [25]	M	60	Yes	-	Yes	-	Yes	Yes	-	Complete occlusion of RCA (CTA)	Yes	Definite
Zateyshchikov *et al.* Russia (2015) [26]	M	45	-	Yes	Yes	-	-	-	-	Yes	-	Definite
Madkaiker *et al.* India (2016) [27]	M	50	Yes	-	Yes	-	Yes	Yes	-	-	-	Definite
Aggarwal *et al.* India (2016) [28]	M	51	Yes	-	-	-	Yes	Yes	-	Yes	Yes	Definite
Dalal *et al.* India (2017) [29]	Fm	66	Yes	-	Yes	-	Yes	-	-	Yes	-	Definite
	M	50	Yes	-	Yes	-	-	Yes	-	Occluded LCx	Yes	Definite
Elder *et al.* Australia (2017) [30]	M	50	No specified data regarding 'infected stent'	-	-	Yes	Yes	Yes	-	Yes	Yes	Possible
Sangolkar *et al.* India (2018) [31]	M	66	No growth	-	-	-	Yes	-	Yes	-	Yes	Possible
Shetty *et al.* India (2018) [32]	M	52	Yes	-	-	-	Yes	-	-	Yes	Yes	Definite
Shah *et al.* India (2018)[33]	M	53	Yes	-	-	-	Yes	Yes	Yes	-	Yes	Definite
Sudhakar, India (2018) [34]	M	49	No growth	-	Yes	-	Yes	Yes	-	-	-	Possible
Messaoud *et al.* Tunisia (2019) [35]	M	71	-	-	Yes	-	Yes	Yes	-	-	Yes	Possible
Reddy *et al.* India (2019) [36]	M	50	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Definite
	M	52	Yes	-	Yes	-	Yes	Low-grade	-	Yes	Yes	Definite
Saeed *et al.* Qatar (2020) [37]	M	50	No growth	-	-	-	Yes	Yes	-	Yes	Yes	Possible

Three or more of these following conditions are favorable for possible CSI: (1) coronary stent implantation in 4 weeks before; (2) repeated procedure through same vascular sheath or complications at the puncture site; (3) bacteremia; (4) fever above 101.5°F without any bacterial infection focus; (5) leukocytosis without any infection or acute coronary syndrome; (6) acute coronary syndrome; (7) cardiac imaging supports the presence of persistent inflammation.

Table 3 Antibiotics and surgical procedure

Author	Antibiotics	Administered Antibiotics	Antibiotics Duration	Surgery	Surgical Procedure
Leroy *et al.* France (1996) [6]	Yes	Ciprofloxacin, Amoxicillin-Clavulanate (1st tx) IV Ciprofloxacin, Netilmicin (2nd tx) Ceftazidime-Amikacin-Ciprofloxacin, Imipenem Cilastatin-Ciprofloxacin (3rd tx)	2 weeks (1st tx) 3 weeks (2nd tx) 3 weeks (3rd tx)	Yes	Infected stent removal, Debridement infected tissue
Bouchart *et al.* France (1997) [7]	Yes	Ceftazidime-Amikacin	4 weeks	Yes	Infected stent removal, CABG
Grewe *et al.* Germany (1999) [8]	No	-	-	No	-
Liu *et al.* USA (2003) [9]	Yes	IV Nafcillin (1st tx) IV Nafcillin + Rifampicin (2nd tx)	20 days (1st tx) 7 weeks (2nd tx)	Yes	Infected stent removal, Debridement, CABG
Hoffman *et al.* Israel (2005) [10]	Yes	IV Cloxacillin	6 weeks	No	-
Alfonso *et al.* Spain (2005) [11]	Yes	Oral Cloxacillin (1st tx) IV Cloxacillin + Gentamycin (2nd tx)	1 week (1st tx) 2 days (2nd tx)	No	-
Marcu *et al.* USA (2005) [12]	Yes	IV Cefazoline	6 weeks	Yes	Infected stent removal, CABG
Singh *et al.* India (2005) [13]	Yes	Cloxacillin, Gentamicin	4 weeks	Yes	CABG
Garg *et al.* USA (2007) [14]	Yes	IV Vancomycin, Oral Rifampicin	>12 Days	No	-
Kishida *et al.* Japan (2007) [15]	Yes	Intravenous adapted antibiotics	>20 days	Yes	Infected stent removal, Aneurysmal excision, Right ventricular wall reconstruction
Schoenkerman and Lundstrom, USA (2009) [16]	Yes	No Data	No data	No	-
Lim *et al.* Singapore (2011) [17]	Yes	IV Vancomycin, IV Linezolid	No data	Yes	Infected stent removal, Debridement, CABG, Pus drainage
Furtado *et al.* India (2011) [18]	Yes	Imipenem, Levofloxacin (1st tx) Imipenem, Levofloxacin (2nd tx)	1 week (1st tx) 6 weeks (2nd tx)	Yes	Infected stent removal, Debridement, CABG
Patel *et al.* USA (2013) [19]	Yes	IV Vancomycin, Oral Rifampicin (1st tx) IV Vancomycin, Oral Rifampicin (2nd tx)	6 weeks (1st tx) 6 weeks (2nd tx)	Yes	Complete aneurysm excision, CABG
Morris *et al.* UK (2013) [20]	Yes	IV Vancomycin, Gentamycin	No data	No	-
Wedekind *et al.* Germany (2013) [21]	Yes	Piperacillin/ Tazobactam, Clarithromycin (1st tx) Cefuroxime, Ciprofloxacin	10 days (1st tx) 12 months (2nd tx)	No	-
Chang *et al.* Taiwan (2014) [22]	No	-	-	Yes	Infected stent removal, CABG
Satish *et al.* India (2015) [23]	Yes	Broad-spectrum antibiotics	No data	Yes	Infected stent removal, Aneurysm removal, CABG
Roubelakis *et al.* UK (2015) [24]	Yes	IV Flucloxacillin	6 weeks	Yes	Infected stent removal, Infected tissue resection, CABG
Sekhar *et al.* India (2015) [25]	Yes	No Data	3 weeks	Yes	Infected stent removal, Abscess removal, CABG
Zateyshchikov *et al.* Russia (2015) [26]	No	-	-	No	-
Madkaiker *et al.* India (2016) [27]	Yes	No Data	No data	Yes	Infected stent removal, Pus drainage, Debridement, CABG
Aggarwal *et al.* India (2016) [28]	Yes	Inj. Meropenem, Teicoplanin	8 weeks	Yes	CABG, Coronary pseudoaneurysmectomy, Necrotic tissue excision,
Dalal *et al.* India (2017) [29]	Yes	IV Meropenem, IV Amikacin, IV Cefepime	10 days (1st tx) 6 weeks (2nd tx)	Yes	Infected stent removal, CABG
	Yes	IV Ceftazidime, IV Vancomycin, IV Gentamycin*	6 weeks *2 weeks due to ototoxicity	Yes	Infected stent removal, Aneurysmal removal
Elder *et al.* Australia (2017) [30]	Yes	IV Ceftriaxone (1st tx) IV Vancomycin (2nd tx) Oral Rifampicin and Fusicid Acid (3rd tx)	1 day (1st tx) 6 weeks (2nd tx) Indefinitely	Yes	Infected stent removal, CABG
Sangolkar *et al.* India (2018) [31]	Yes	IV Cefepime, Ciprofloxacin, Gentamycin	2 weeks	Yes	Infected stent removal, Debridement
Shetty *et al.* India (2018) [32]	Yes	No data	4 weeks	Yes	Infected stent removal, Aneurysm removal, Debridement, CABG
Shah *et al.* India (2018) [33]	Yes	No data	No data	Yes	Infected stent removal, Aneurysm removal, Debridement, CABG
Sudhakar, India (2018) [34]	Yes	IV piperacillin/tazobactam IV Meropenem, IV Gentamycin*, IV Ciprofloxacin	5 days (switched) 6 weeks *2 weeks then switched to Ciprofloxacin	Yes	Infected stent removal, Mitral valve replacement, Debridement, CABG
Messaoud *et al.* Tunisia (2019) [35]	Yes	IV Vancomycin, IV Gentamycin, Oral Rifampicin	6 weeks	No	-
Reddy *et al.* India (2019) [36]	Yes	No data	4 weeks	Yes	Infected stent removal, CABG
	Yes	IV Teicoplanin	4 weeks	Yes	Infected stent removal
Saeed *et al.* Qatar (2020) [37]	Yes	IV Piperacillin-Tazobactam, Vancomycin (1st tx) Penicillin G (2nd tx) IV Ceftriaxone (3rd tx) Oral Amoxicillin (4th tx)	5 days (switched) No data (2nd tx) 6 weeks (3rd tx) 6 months (4th tx)	Yes	Infected stent removal, CABG

CABG, coronary artery bypass surgery; IV, intravenous; tx: therapy.

The current systematic review demonstrated a mortality rate among CSI patients of 26.47%. This rate is remarkably lower than those reported in previous reviews. For instance, previous reviews of 23 and 17 CSI cases yielded mortality rates of 39 and 47%, respectively [5,39]. One review also revealed mortality rates among patients with stent infections in coronary and noncoronary arteries of 48 and 23% [40]. The current review excluded reports mentioning a history of hemodialysis or surgery to minimize infection source bias. Meanwhile, previous reviews included all CSI cases, which is the most likely reason for the higher mortality rates [41].

Benefits to further clinical practice

The increasing use of PCI procedures and DES implantations could increase the incidence of CSI. Therefore, an updated outlook of PCI-related infections, especially CSI, is urgently needed. This review provides updated evidence to improve the recognition and management of CSI cases.

CSI is the rarest complication related to PCI, and it is avoidable. Patient preparation, personnel and laboratory cleaning significantly minimize the risk of infection [5]. Consequently, conditions such as sterility inadequacy, repeated local site punctures (primarily in the groin area), balloon or catheter re-utilization without adequate sterilization, repeated wire manipulations and prolonged indwelling catheterization can increase the risk of stent infection [36].

Study limitations

The present review has several limitations. First, this review excluded cases reported before the 2000s because most of these were inaccessible. Second, this review focuses solely on CSI cases without a history of hemodialysis or surgery, and, hence, evidence regarding CSI under these conditions is limited. However, hemodialysis and surgery are considered significant infection sources, which may cause bias [42]. Finally, data regarding patients' risk factors (diabetes, hypertension or any chronic illness) were not extensively assessed, as such factors are rarely mentioned.

Conclusion

This systematic review provides an updated outlook on CSI cases – namely, regarding clinical presentations, diagnostic methods, stents and vessel pathology, causative pathogens, treatments, complications and outcomes. This review could improve the recognition and management of CSI cases.

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The datasets used and/or analyzed during the current review are available from the corresponding author on reasonable request.

Conflicts of interest

There are no conflicts of interest.

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