

Carotid Stenosis Treatment: Systematic Review with SAIMSARA.

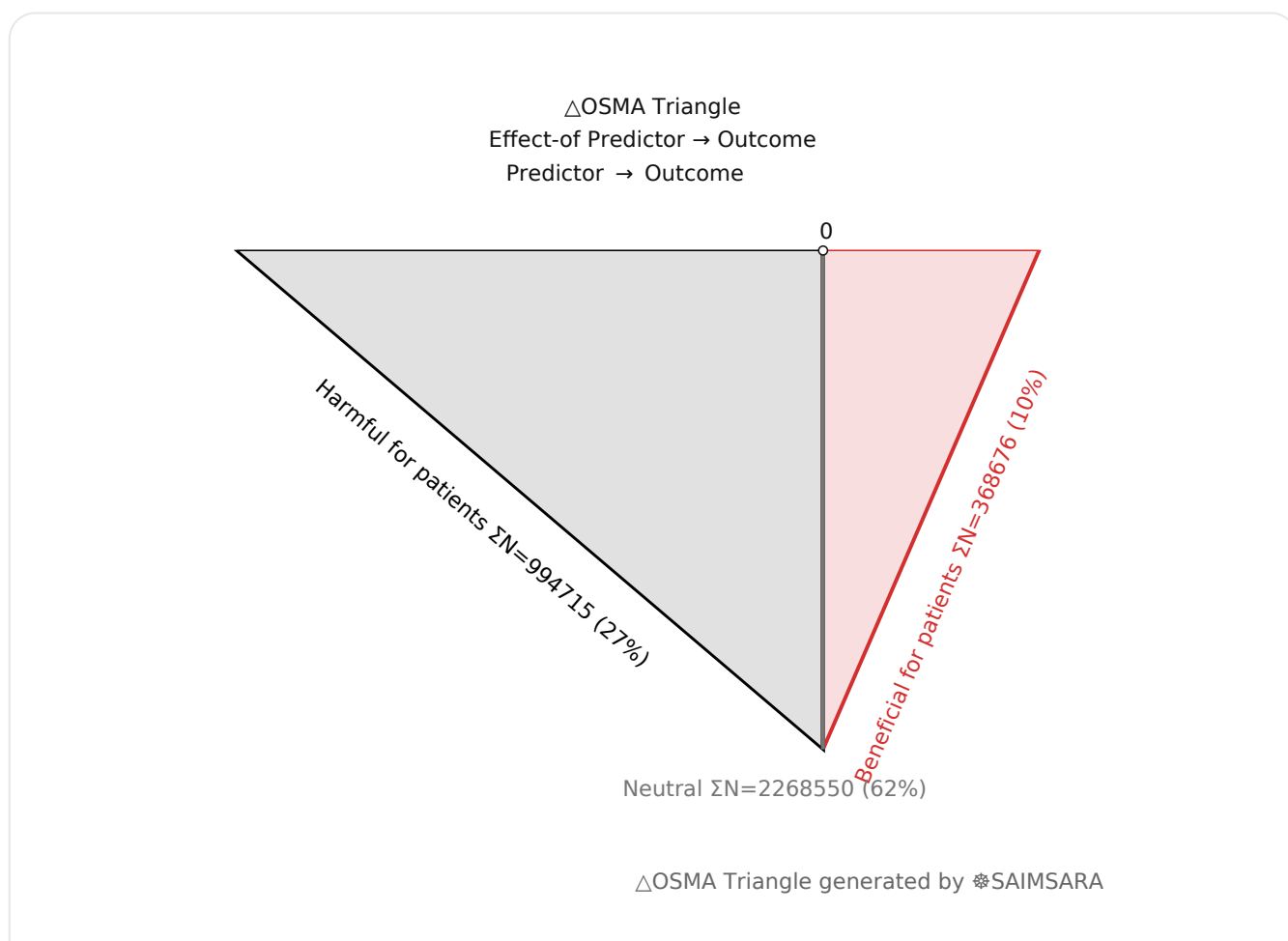
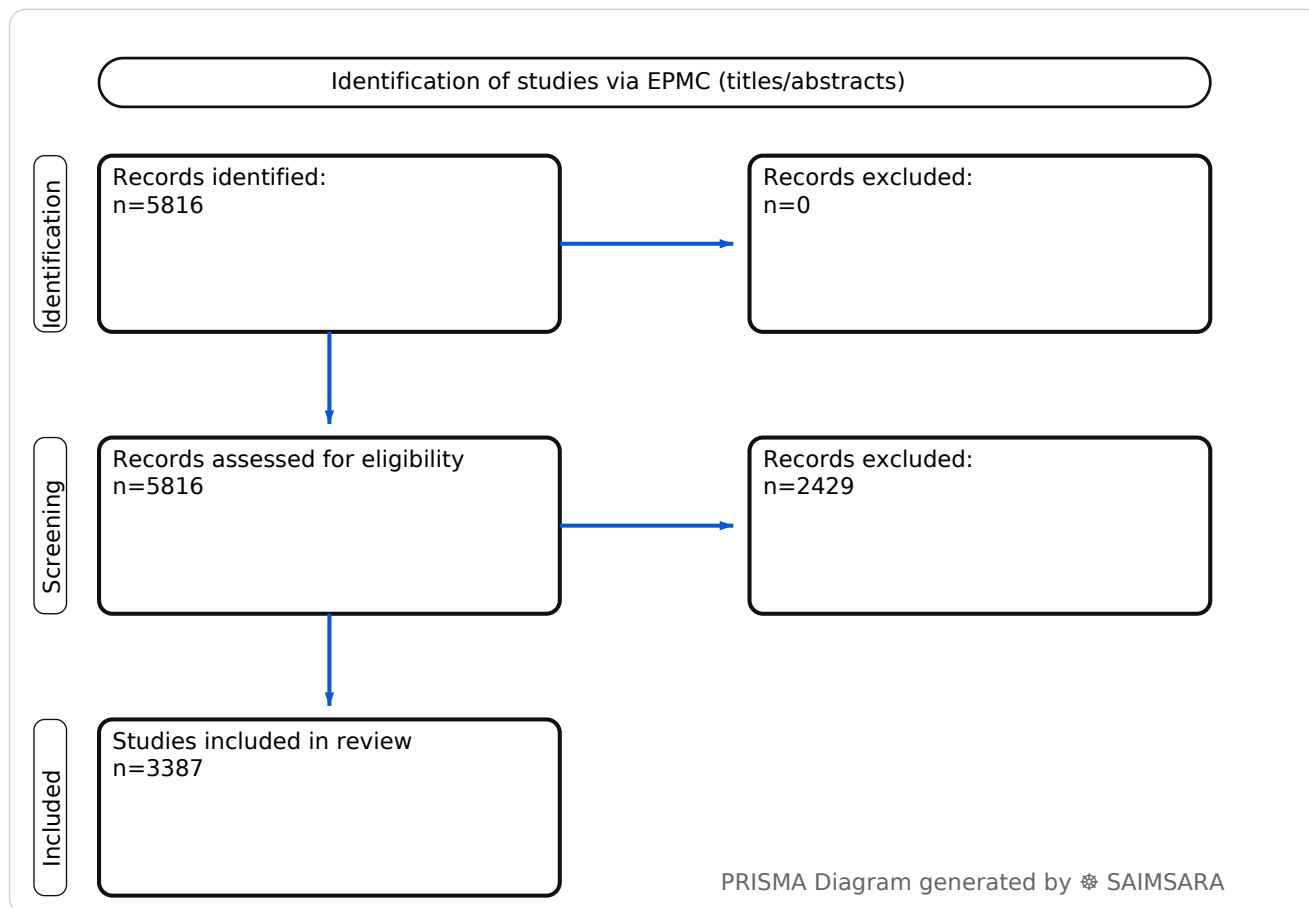
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Abstract: The aim of this paper is to systematically review and synthesize current research on carotid stenosis treatment, identifying key outcomes, comparative efficacies of different modalities, emerging techniques, and critical areas for future investigation. The review utilises 3387 studies with 3631941 total participants (naïve ΣN). A meta-analysis of randomized controlled trials found that carotid artery stenting (CAS) was associated with an increased risk of periprocedural stroke (relative risk, 1.49, 95% CI, 1.11 to 2.01; risk difference, 1.7%; 95% CI, 0.3 to 3.0) and a long-term stroke risk (relative risk, 1.36; 95% CI, 1.16 to 1.61) compared to carotid endarterectomy (CEA). This finding, however, exists within a complex landscape of evidence, where optimal medical therapy remains fundamental, and emerging techniques like TCAR show promise, particularly for high-risk patients. The heterogeneity of studies, including variations in design and outcome reporting, limits the certainty of direct comparisons across all modalities. Clinicians should continue to individualize treatment decisions based on patient-specific risk factors, symptom status, and anatomical considerations, while researchers prioritize large, well-designed comparative effectiveness trials to refine guidelines and improve patient outcomes.

Keywords: Carotid stenosis; Carotid endarterectomy; Carotid artery stenting; Endovascular treatment; Stroke prevention; C

Review Stats

- Generated: 2026-02-04 11:03:06 CET
- Plan: Pro (expanded craft tokens; source: Europe PMC)
- Source: Europe PMC
- Scope: Titles/Abstracts (tiab)
- Keyword Gate: Fuzzy ($\geq 60\%$ of required terms, minimum 2 terms matched in title/abstract)
- Total Abstracts/Papers: 5816
- Downloaded Abstracts/Papers: 5816
- Included original Abstracts/Papers: 3387
- Total study participants (naïve ΣN): 3631941



Outcome-Sentiment Meta-Analysis (OSMA): (LLM-only)

Frame: Effect-of Predictor → Outcome • *Source:* Europe PMC

Outcome: Outcome Typical timepoints: peri/post-op, 30-day. Reported metrics: %, CI, p.

Common endpoints: Common endpoints: complications, mortality, occlusion.

Predictor: Predictor — exposure/predictor. Doses/units seen: 10 ml, 70 mg, 20 kg, 50 ml, 45 ml, 80 mg.... Routes seen: intravenous, iv, oral, sc. Typical comparator: cea, the conventional method, common carotid artery, carotid wallstent....

- **1) Beneficial for patients** — Outcome with Predictor — [4], [6], [7], [12], [18], [19], [21], [23], [25], [26], [27], [28], [32], [34], [35], [37], [38], [41], [44], [81], [83], [87], [89], [90], [102], [103], [105], [106], [108], [112], [113], [115], [116], [118], [120], [121], [122], [124], [125], [127], [129], [130], [132], [133], [137], [140], [142], [144], [146], [149], [150], [176], [180], [181], [184], [187], [190], [194], [196], [199], [200], [203], [207], [208], [213], [214], [216], [217], [224], [228], [229], [230], [232], [233], [235], [239], [240], [242], [243], [244], [246], [250], [252], [256], [257], [259], [263], [265], [268], [270], [271], [272], [275], [276], [280], [281], [291], [292], [301], [303], [305], [308], [310], [313], [314], [315], [316], [317], [318], [319], [320], [321], [322], [323], [325], [326], [327], [330], [331], [332], [333], [334], [339], [341], [344], [345], [348], [350], [356], [357], [358], [359], [360], [364], [372], [375], [379], [381], [383], [384], [386], [388], [391], [392], [393], [396], [397], [398], [399], [400], [426], [429], [430], [431], [433], [435], [436], [437], [438], [439], [446], [448], [451], [452], [460], [461], [462], [468], [474], [476], [478], [479], [484], [486], [491], [495], [497], [500], [528], [529], [533], [535], [538], [544], [549], [550], [602], [603], [604], [607], [608], [616], [617], [619], [620], [622], [626], [627], [628], [630], [631], [632], [634], [635], [636], [638], [640], [641], [643], [644], [645], [646], [647], [727], [728], [731], [732], [734], [735], [741], [744], [748], [749], [753], [754], [755], [759], [760], [761], [762], [766], [767], [770], [772], [774], [801], [812], [813], [816], [817], [819], [820], [822], [827], [828], [830], [831], [832], [833], [834], [835], [836], [841], [842], [843], [844], [848], [851], [856], [857], [858], [861], [862], [865], [867], [869], [870], [872], [875], [876], [884], [886], [951], [952], [954], [956], [957], [962], [963], [964], [965], [966], [970], [971], [972], [978], [980], [981], [983], [984], [985], [986], [987], [988], [989], [992], [994], [995], [998], [999], [1003], [1004], [1006], [1007], [1008], [1010], [1013], [1016], [1017], [1020], [1023], [1025], [1028], [1030], [1032], [1036], [1039], [1041], [1042], [1044], [1046], [1047], [1048], [1049], [1065], [1071], [1075], [1076], [1079], [1081], [1085], [1092], [1095], [1096], [1100], [1151], [1153], [1156], [1157], [1158], [1161], [1163], [1166], [1168], [1170], [1171], [1173], [1175], [1251], [1255], [1256], [1257], [1258], [1259], [1261], [1267], [1268], [1269], [1270], [1271], [1274],

[1280], [1281], [1284], [1285], [1290], [1291], [1293], [1295], [1296], [1297], [1298], [1299], [1313], [1318], [1320], [1322], [1325], [1327], [1330], [1331], [1334], [1337], [1340], [1341], [1343], [1345], [1347], [1350], [1353], [1354], [1355], [1358], [1360], [1362], [1363], [1368], [1371], [1374], [1431], [1432], [1434], [1435], [1436], [1437], [1441], [1442], [1443], [1445], [1449], [1452], [1453], [1454], [1456], [1459], [1464], [1466], [1469], [1474], [1477], [1483], [1484], [1485], [1486], [1487], [1488], [1489], [1492], [1493], [1494], [1495], [1497], [1499], [1500], [1502], [1503], [1504], [1510], [1512], [1513], [1516], [1521], [1526], [1530], [1533], [1534], [1537], [1538], [1540], [1542], [1543], [1545], [1547], [1549], [1578], [1581], [1585], [1588], [1591], [1600], [1602], [1605], [1606], [1608], [1611], [1613], [1617], [1619], [1620], [1622], [1623], [1624], [1727], [1729], [1731], [1734], [1738], [1740], [1743], [1747], [1750], [1834], [1835], [1836], [1847], [1850], [1876], [1878], [1891], [1897], [1930], [1931], [1932], [1933], [1934], [1937], [1945], [1946], [1949], [1953], [1954], [1957], [1958], [1964], [1967], [1968], [1970], [1974], [1975], [2009], [2013], [2015], [2016], [2018], [2019], [2020], [2025], [2051], [2053], [2054], [2058], [2059], [2060], [2062], [2064], [2066], [2068], [2069], [2070], [2072], [2073], [2075], [2078], [2079], [2082], [2083], [2084], [2085], [2086], [2091], [2094], [2095], [2099], [2100], [2103], [2105], [2108], [2109], [2112], [2114], [2120], [2122], [2123], [2125], [2131], [2141], [2149], [2154], [2161], [2163], [2167], [2168], [2172], [2175], [2176], [2180], [2183], [2189], [2196], [2199], [2251], [2261], [2262], [2263], [2264], [2267], [2274], [2334], [2335], [2337], [2340], [2343], [2344], [2345], [2346], [2347], [2349], [2350], [2354], [2356], [2358], [2359], [2360], [2361], [2362], [2363], [2365], [2373], [2375], [2377], [2384], [2385], [2387], [2388], [2389], [2390], [2394], [2395], [2398], [2401], [2404], [2407], [2408], [2409], [2416], [2418], [2419], [2422], [2423], [2424], [2425], [2427], [2428], [2430], [2431], [2432], [2434], [2436], [2437], [2439], [2445], [2447], [2448], [2449], [2452], [2456], [2458], [2459], [2460], [2462], [2463], [2464], [2465], [2466], [2467], [2470], [2472], [2473], [2475], [2506], [2508], [2509], [2510], [2514], [2516], [2520], [2522], [2524], [2525], [2526], [2532], [2533], [2534], [2538], [2540], [2541], [2544], [2545], [2546], [2547], [2548], [2550], [2553], [2554], [2555], [2557], [2559], [2561], [2563], [2566], [2567], [2569], [2570], [2571], [2572], [2575], [2626], [2629], [2632], [2637], [2646], [2648], [2650], [2676], [2677], [2678], [2682], [2685], [2686], [2689], [2697], [2699], [2700], [2777], [2780], [2784], [2786], [2787], [2788], [2789], [2793], [2796], [2799], [2800], [2804], [2806], [2807], [2814], [2816], [2817], [2820], [2821], [2822], [2825], [2826], [2830], [2831], [2834], [2836], [2837], [2840], [2841], [2842], [2844], [2847], [2848], [2852], [2857], [2860], [2861], [2865], [2870], [2909], [2922], [2938], [2939], [2940], [2942], [2944], [2947], [2948], [3101], [3103], [3104], [3105], [3107], [3111], [3115], [3116], [3119], [3123], [3125], [3176], [3178], [3179], [3181], [3182], [3183], [3184], [3186], [3190], [3191], [3193], [3198], [3199], [3200], [3232], [3235], [3237],

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- **2) Harmful for patients** — Outcome with Predictor — [3], [8], [17], [20], [30], [40], [48], [49], [50], [92], [111], [126], [128], [131], [134], [135], [136], [138], [141], [143], [145], [148], [178], [185], [186], [189], [192], [193], [195], [197], [206], [210], [211], [219], [221], [225], [226], [227], [234], [238], [247], [253], [267], [269], [274], [277], [284], [285], [286], [289], [293], [294], [296], [297], [300], [302], [307], [329], [340], [347], [351], [366], [368], [370], [371], [377], [394], [403], [404], [408], [411], [412], [414], [417], [419], [425], [427], [441], [444], [457], [458], [463], [467], [469], [470], [475], [477], [498], [526], [530], [542], [545], [547], [601], [609], [611], [612], [613], [633], [642], [648], [650], [743], [746], [747], [752], [757], [765], [768], [769], [773], [775], [802], [805], [806], [807], [808], [811], [814], [821], [825], [826], [829], [850], [853], [859], [873], [877], [880], [881], [885], [889], [890], [893], [894], [897], [898], [899], [900], [960], [968], [969], [975], [977], [991], [997], [1000], [1002], [1005], [1018], [1021], [1026], [1029], [1033], [1040], [1043], [1045], [1051], [1061], [1066], [1069], [1070], [1077], [1078], [1080], [1084], [1089], [1091], [1093], [1097], [1152], [1154], [1160], [1164], [1165], [1167], [1252], [1254], [1262], [1265], [1283], [1294], [1300], [1305], [1309], [1311], [1314], [1317], [1321], [1324], [1326], [1328], [1332], [1336], [1338], [1339], [1342], [1346], [1348], [1349], [1351], [1352], [1359], [1364], [1365], [1375], [1426], [1427], [1429], [1440], [1446], [1451], [1455], [1458], [1461], [1463], [1465], [1467], [1468], [1470], [1472], [1473], [1475], [1476], [1478], [1496], [1498], [1505], [1507], [1508], [1509], [1511], [1514], [1518], [1520], [1522], [1524], [1525], [1532], [1550], [1576], [1579], [1580], [1589], [1594], [1595], [1596], [1597], [1599], [1601], [1604], [1609], [1610], [1614], [1616], [1733], [1742], [1749], [1830], [1831], [1840], [1879], [1887], [1893], [1896], [1899], [1900], [1926], [1935], [1938], [1939], [1941], [1942], [1944], [1947], [1948], [1950], [1959], [1963], [1966], [1971], [2001], [2005], [2007], [2008], [2011], [2017], [2022], [2055], [2056], [2057], [2061], [2067], [2076], [2077], [2081], [2088], [2089], [2097], [2102], [2106], [2107], [2113], [2119], [2130], [2132], [2135], [2136], [2138], [2140], [2144], [2145], [2152], [2153], [2156], [2158], [2160], [2162], [2164], [2166], [2170], [2171], [2174], [2181], [2182], [2188], [2191], [2192], [2193], [2195], [2200], [2257], [2275], [2328], [2332], [2336], [2352], [2353], [2355], [2364], [2366], [2367], [2368], [2370], [2371], [2372], [2374], [2378], [2399], [2400], [2402], [2405], [2410], [2411], [2414], [2415], [2420], [2421], [2426], [2429], [2442], [2443], [2446], [2450], [2457], [2461], [2474], [2504], [2507], [2515], [2519], [2521], [2523], [2528], [2529], [2536], [2552], [2558], [2560], [2562], [2564], [2565], [2573], [2574], [2627], [2633], [2639], [2643], [2647], [2690], [2691],

[2790], [2798], [2815], [2819], [2827], [2829], [2833], [2838], [2843], [2845], [2846], [2849], [2850], [2853], [2854], [2858], [2862], [2863], [2864], [2869], [2875], [2903], [2905], [2914], [2918], [2921], [2923], [2925], [2927], [2928], [2929], [2930], [2934], [2936], [2937], [2949], [3106], [3109], [3110], [3113], [3124], [3177], [3180], [3185], [3192], [3194], [3196], [3227], [3244], [3245], [3248], [3258], [3265], [3267], [3274], [3312], [3314], [3315], [3317], [3325], [3327], [3328], [3329], [3332], [3333], [3334], [3341], [3343], [3350], [3379], [3380], [3383], [3384], [3387] — $\Sigma N=994715$

- **3) No clear effect** — Outcome with Predictor — [1], [2], [5], [9], [10], [11], [13], [14], [15], [16], [22], [24], [29], [31], [33], [36], [39], [42], [43], [45], [46], [47], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [82], [84], [85], [86], [88], [91], [93], [94], [95], [96], [97], [98], [99], [100], [101], [104], [107], [109], [110], [114], [117], [119], [123], [139], [147], [151], [152], [153], [154], [155], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167], [168], [169], [170], [171], [172], [173], [174], [175], [177], [179], [182], [183], [188], [191], [198], [201], [202], [204], [205], [209], [212], [215], [218], [220], [222], [223], [231], [236], [237], [241], [245], [248], [249], [251], [254], [255], [258], [260], [261], [262], [264], [266], [273], [278], [279], [282], [283], [287], [288], [290], [295], [298], [299], [304], [306], [309], [311], [312], [324], [328], [335], [336], [337], [338], [342], [343], [346], [349], [352], [353], [354], [355], [361], [362], [363], [365], [367], [369], [373], [374], [376], [378], [380], [382], [385], [387], [389], [390], [395], [401], [402], [405], [406], [407], [409], [410], [413], [415], [416], [418], [420], [421], [422], [423], [424], [428], [432], [434], [440], [442], [443], [445], [447], [449], [450], [453], [454], [455], [456], [459], [464], [465], [466], [471], [472], [473], [480], [481], [482], [483], [485], [487], [488], [489], [490], [492], [493], [494], [496], [499], [501], [502], [503], [504], [505], [506], [507], [508], [509], [510], [511], [512], [513], [514], [515], [516], [517], [518], [519], [520], [521], [522], [523], [524], [525], [527], [531], [532], [534], [536], [537], [539], [540], [541], [543], [546], [548], [551], [552], [553], [554], [555], [556], [557], [558], [559], [560], [561], [562], [563], [564], [565], [566], [567], [568], [569], [570], [571], [572], [573], [574], [575], [576], [577], [578], [579], [580], [581], [582], [583], [584], [585], [586], [587], [588], [589], [590], [591], [592], [593], [594], [595], [596], [597], [598], [599], [600], [605], [606], [610], [614], [615], [618], [621], [623], [624], [625], [629], [637], [639], [649], [651], [652], [653], [654], [655], [656], [657], [658], [659], [660], [661], [662], [663], [664], [665], [666], [667], [668], [669], [670], [671], [672], [673], [674], [675], [676], [677], [678], [679], [680], [681], [682], [683], [684], [685], [686], [687], [688], [689], [690], [691], [692], [693], [694], [695], [696], [697], [698], [699], [700], [701], [702], [703], [704], [705], [706], [707], [708], [709], [710], [711], [712], [713], [714], [715], [716], [717], [718], [719], [720], [721], [722], [723], [724],

[725], [726], [729], [730], [733], [736], [737], [738], [739], [740], [742], [745], [750], [751], [756], [758], [763], [764], [771], [776], [777], [778], [779], [780], [781], [782], [783], [784], [785], [786], [787], [788], [789], [790], [791], [792], [793], [794], [795], [796], [797], [798], [799], [800], [803], [804], [809], [810], [815], [818], [823], [824], [837], [838], [839], [840], [845], [846], [847], [849], [852], [854], [855], [860], [863], [864], [866], [868], [871], [874], [878], [879], [882], [883], [887], [888], [891], [892], [895], [896], [901], [902], [903], [904], [905], [906], [907], [908], [909], [910], [911], [912], [913], [914], [915], [916], [917], [918], [919], [920], [921], [922], [923], [924], [925], [926], [927], [928], [929], [930], [931], [932], [933], [934], [935], [936], [937], [938], [939], [940], [941], [942], [943], [944], [945], [946], [947], [948], [949], [950], [953], [955], [958], [959], [961], [967], [973], [974], [976], [979], [982], [990], [993], [996], [1001], [1009], [1011], [1012], [1014], [1015], [1019], [1022], [1024], [1027], [1031], [1034], [1035], [1037], [1038], [1050], [1052], [1053], [1054], [1055], [1056], [1057], [1058], [1059], [1060], [1062], [1063], [1064], [1067], [1068], [1072], [1073], [1074], [1082], [1083], [1086], [1087], [1088], [1090], [1094], [1098], [1099], [1101], [1102], [1103], [1104], [1105], [1106], [1107], [1108], [1109], [1110], [1111], [1112], [1113], [1114], [1115], [1116], [1117], [1118], [1119], [1120], [1121], [1122], [1123], [1124], [1125], [1126], [1127], [1128], [1129], [1130], [1131], [1132], [1133], [1134], [1135], [1136], [1137], [1138], [1139], [1140], [1141], [1142], [1143], [1144], [1145], [1146], [1147], [1148], [1149], [1150], [1155], [1159], [1162], [1169], [1172], [1174], [1176], [1177], [1178], [1179], [1180], [1181], [1182], [1183], [1184], [1185], [1186], [1187], [1188], [1189], [1190], [1191], [1192], [1193], [1194], [1195], [1196], [1197], [1198], [1199], [1200], [1201], [1202], [1203], [1204], [1205], [1206], [1207], [1208], [1209], [1210], [1211], [1212], [1213], [1214], [1215], [1216], [1217], [1218], [1219], [1220], [1221], [1222], [1223], [1224], [1225], [1226], [1227], [1228], [1229], [1230], [1231], [1232], [1233], [1234], [1235], [1236], [1237], [1238], [1239], [1240], [1241], [1242], [1243], [1244], [1245], [1246], [1247], [1248], [1249], [1250], [1253], [1260], [1263], [1264], [1266], [1272], [1273], [1275], [1276], [1277], [1278], [1279], [1282], [1286], [1287], [1288], [1289], [1292], [1301], [1302], [1303], [1304], [1306], [1307], [1308], [1310], [1312], [1315], [1316], [1319], [1323], [1329], [1333], [1335], [1344], [1356], [1357], [1361], [1366], [1367], [1369], [1370], [1372], [1373], [1376], [1377], [1378], [1379], [1380], [1381], [1382], [1383], [1384], [1385], [1386], [1387], [1388], [1389], [1390], [1391], [1392], [1393], [1394], [1395], [1396], [1397], [1398], [1399], [1400], [1401], [1402], [1403], [1404], [1405], [1406], [1407], [1408], [1409], [1410], [1411], [1412], [1413], [1414], [1415], [1416], [1417], [1418], [1419], [1420], [1421], [1422], [1423], [1424], [1425], [1428], [1430], [1433], [1438], [1439], [1444], [1447], [1448], [1450], [1457], [1460], [1462], [1471], [1479], [1480], [1481], [1482], [1490], [1491], [1501], [1506], [1515], [1517], [1519], [1523], [1527], [1528], [1529], [1531],

[1535], [1536], [1539], [1541], [1544], [1546], [1548], [1551], [1552], [1553], [1554], [1555], [1556], [1557], [1558], [1559], [1560], [1561], [1562], [1563], [1564], [1565], [1566], [1567], [1568], [1569], [1570], [1571], [1572], [1573], [1574], [1575], [1577], [1582], [1583], [1584], [1586], [1587], [1590], [1592], [1593], [1598], [1603], [1607], [1612], [1615], [1618], [1621], [1625], [1626], [1627], [1628], [1629], [1630], [1631], [1632], [1633], [1634], [1635], [1636], [1637], [1638], [1639], [1640], [1641], [1642], [1643], [1644], [1645], [1646], [1647], [1648], [1649], [1650], [1651], [1652], [1653], [1654], [1655], [1656], [1657], [1658], [1659], [1660], [1661], [1662], [1663], [1664], [1665], [1666], [1667], [1668], [1669], [1670], [1671], [1672], [1673], [1674], [1675], [1676], [1677], [1678], [1679], [1680], [1681], [1682], [1683], [1684], [1685], [1686], [1687], [1688], [1689], [1690], [1691], [1692], [1693], [1694], [1695], [1696], [1697], [1698], [1699], [1700], [1701], [1702], [1703], [1704], [1705], [1706], [1707], [1708], [1709], [1710], [1711], [1712], [1713], [1714], [1715], [1716], [1717], [1718], [1719], [1720], [1721], [1722], [1723], [1724], [1725], [1726], [1728], [1730], [1732], [1735], [1736], [1737], [1739], [1741], [1744], [1745], [1746], [1748], [1751], [1752], [1753], [1754], [1755], [1756], [1757], [1758], [1759], [1760], [1761], [1762], [1763], [1764], [1765], [1766], [1767], [1768], [1769], [1770], [1771], [1772], [1773], [1774], [1775], [1776], [1777], [1778], [1779], [1780], [1781], [1782], [1783], [1784], [1785], [1786], [1787], [1788], [1789], [1790], [1791], [1792], [1793], [1794], [1795], [1796], [1797], [1798], [1799], [1800], [1801], [1802], [1803], [1804], [1805], [1806], [1807], [1808], [1809], [1810], [1811], [1812], [1813], [1814], [1815], [1816], [1817], [1818], [1819], [1820], [1821], [1822], [1823], [1824], [1825], [1826], [1827], [1828], [1829], [1832], [1833], [1837], [1838], [1839], [1841], [1842], [1843], [1844], [1845], [1846], [1848], [1849], [1851], [1852], [1853], [1854], [1855], [1856], [1857], [1858], [1859], [1860], [1861], [1862], [1863], [1864], [1865], [1866], [1867], [1868], [1869], [1870], [1871], [1872], [1873], [1874], [1875], [1877], [1880], [1881], [1882], [1883], [1884], [1885], [1886], [1888], [1889], [1890], [1892], [1894], [1895], [1898], [1901], [1902], [1903], [1904], [1905], [1906], [1907], [1908], [1909], [1910], [1911], [1912], [1913], [1914], [1915], [1916], [1917], [1918], [1919], [1920], [1921], [1922], [1923], [1924], [1925], [1927], [1928], [1929], [1936], [1940], [1943], [1951], [1952], [1955], [1956], [1960], [1961], [1962], [1965], [1969], [1972], [1973], [1976], [1977], [1978], [1979], [1980], [1981], [1982], [1983], [1984], [1985], [1986], [1987], [1988], [1989], [1990], [1991], [1992], [1993], [1994], [1995], [1996], [1997], [1998], [1999], [2000], [2002], [2003], [2004], [2006], [2010], [2012], [2014], [2021], [2023], [2024], [2026], [2027], [2028], [2029], [2030], [2031], [2032], [2033], [2034], [2035], [2036], [2037], [2038], [2039], [2040], [2041], [2042], [2043], [2044], [2045], [2046], [2047], [2048], [2049], [2050], [2052], [2063], [2065], [2071], [2074], [2080], [2087], [2090], [2092], [2093], [2096], [2098], [2101], [2104], [2110], [2111], [2115], [2116], [2117], [2118], [2121], [2124],

[2126], [2127], [2128], [2129], [2133], [2134], [2137], [2139], [2142], [2143], [2146], [2147], [2148], [2150], [2151], [2155], [2157], [2159], [2165], [2169], [2173], [2177], [2178], [2179], [2184], [2185], [2186], [2187], [2190], [2194], [2197], [2198], [2201], [2202], [2203], [2204], [2205], [2206], [2207], [2208], [2209], [2210], [2211], [2212], [2213], [2214], [2215], [2216], [2217], [2218], [2219], [2220], [2221], [2222], [2223], [2224], [2225], [2226], [2227], [2228], [2229], [2230], [2231], [2232], [2233], [2234], [2235], [2236], [2237], [2238], [2239], [2240], [2241], [2242], [2243], [2244], [2245], [2246], [2247], [2248], [2249], [2250], [2252], [2253], [2254], [2255], [2256], [2258], [2259], [2260], [2265], [2266], [2268], [2269], [2270], [2271], [2272], [2273], [2276], [2277], [2278], [2279], [2280], [2281], [2282], [2283], [2284], [2285], [2286], [2287], [2288], [2289], [2290], [2291], [2292], [2293], [2294], [2295], [2296], [2297], [2298], [2299], [2300], [2301], [2302], [2303], [2304], [2305], [2306], [2307], [2308], [2309], [2310], [2311], [2312], [2313], [2314], [2315], [2316], [2317], [2318], [2319], [2320], [2321], [2322], [2323], [2324], [2325], [2326], [2327], [2329], [2330], [2331], [2333], [2338], [2339], [2341], [2342], [2348], [2351], [2357], [2369], [2376], [2379], [2380], [2381], [2382], [2383], [2386], [2391], [2392], [2393], [2396], [2397], [2403], [2406], [2412], [2413], [2417], [2433], [2435], [2438], [2440], [2441], [2444], [2451], [2453], [2454], [2455], [2468], [2469], [2471], [2476], [2477], [2478], [2479], [2480], [2481], [2482], [2483], [2484], [2485], [2486], [2487], [2488], [2489], [2490], [2491], [2492], [2493], [2494], [2495], [2496], [2497], [2498], [2499], [2500], [2501], [2502], [2503], [2505], [2511], [2512], [2513], [2517], [2518], [2527], [2530], [2531], [2535], [2537], [2539], [2542], [2543], [2549], [2551], [2556], [2568], [2576], [2577], [2578], [2579], [2580], [2581], [2582], [2583], [2584], [2585], [2586], [2587], [2588], [2589], [2590], [2591], [2592], [2593], [2594], [2595], [2596], [2597], [2598], [2599], [2600], [2601], [2602], [2603], [2604], [2605], [2606], [2607], [2608], [2609], [2610], [2611], [2612], [2613], [2614], [2615], [2616], [2617], [2618], [2619], [2620], [2621], [2622], [2623], [2624], [2625], [2628], [2630], [2631], [2634], [2635], [2636], [2638], [2640], [2641], [2642], [2644], [2645], [2649], [2651], [2652], [2653], [2654], [2655], [2656], [2657], [2658], [2659], [2660], [2661], [2662], [2663], [2664], [2665], [2666], [2667], [2668], [2669], [2670], [2671], [2672], [2673], [2674], [2675], [2679], [2680], [2681], [2683], [2684], [2687], [2688], [2692], [2693], [2694], [2695], [2696], [2698], [2701], [2702], [2703], [2704], [2705], [2706], [2707], [2708], [2709], [2710], [2711], [2712], [2713], [2714], [2715], [2716], [2717], [2718], [2719], [2720], [2721], [2722], [2723], [2724], [2725], [2726], [2727], [2728], [2729], [2730], [2731], [2732], [2733], [2734], [2735], [2736], [2737], [2738], [2739], [2740], [2741], [2742], [2743], [2744], [2745], [2746], [2747], [2748], [2749], [2750], [2751], [2752], [2753], [2754], [2755], [2756], [2757], [2758], [2759], [2760], [2761], [2762], [2763], [2764], [2765], [2766], [2767], [2768], [2769], [2770], [2771], [2772], [2773], [2774], [2775], [2776], [2778], [2779], [2781],

[2782], [2783], [2785], [2791], [2792], [2794], [2795], [2797], [2801], [2802], [2803], [2805], [2808], [2809], [2810], [2811], [2812], [2813], [2818], [2823], [2824], [2828], [2832], [2835], [2839], [2851], [2855], [2856], [2859], [2866], [2867], [2868], [2871], [2872], [2873], [2874], [2876], [2877], [2878], [2879], [2880], [2881], [2882], [2883], [2884], [2885], [2886], [2887], [2888], [2889], [2890], [2891], [2892], [2893], [2894], [2895], [2896], [2897], [2898], [2899], [2900], [2901], [2902], [2904], [2906], [2907], [2908], [2910], [2911], [2912], [2913], [2915], [2916], [2917], [2919], [2920], [2924], [2926], [2931], [2932], [2933], [2935], [2941], [2943], [2945], [2946], [2950], [2951], [2952], [2953], [2954], [2955], [2956], [2957], [2958], [2959], [2960], [2961], [2962], [2963], [2964], [2965], [2966], [2967], [2968], [2969], [2970], [2971], [2972], [2973], [2974], [2975], [2976], [2977], [2978], [2979], [2980], [2981], [2982], [2983], [2984], [2985], [2986], [2987], [2988], [2989], [2990], [2991], [2992], [2993], [2994], [2995], [2996], [2997], [2998], [2999], [3000], [3001], [3002], [3003], [3004], [3005], [3006], [3007], [3008], [3009], [3010], [3011], [3012], [3013], [3014], [3015], [3016], [3017], [3018], [3019], [3020], [3021], [3022], [3023], [3024], [3025], [3026], [3027], [3028], [3029], [3030], [3031], [3032], [3033], [3034], [3035], [3036], [3037], [3038], [3039], [3040], [3041], [3042], [3043], [3044], [3045], [3046], [3047], [3048], [3049], [3050], [3051], [3052], [3053], [3054], [3055], [3056], [3057], [3058], [3059], [3060], [3061], [3062], [3063], [3064], [3065], [3066], [3067], [3068], [3069], [3070], [3071], [3072], [3073], [3074], [3075], [3076], [3077], [3078], [3079], [3080], [3081], [3082], [3083], [3084], [3085], [3086], [3087], [3088], [3089], [3090], [3091], [3092], [3093], [3094], [3095], [3096], [3097], [3098], [3099], [3100], [3102], [3108], [3112], [3114], [3117], [3118], [3120], [3121], [3122], [3126], [3127], [3128], [3129], [3130], [3131], [3132], [3133], [3134], [3135], [3136], [3137], [3138], [3139], [3140], [3141], [3142], [3143], [3144], [3145], [3146], [3147], [3148], [3149], [3150], [3151], [3152], [3153], [3154], [3155], [3156], [3157], [3158], [3159], [3160], [3161], [3162], [3163], [3164], [3165], [3166], [3167], [3168], [3169], [3170], [3171], [3172], [3173], [3174], [3175], [3187], [3188], [3189], [3195], [3197], [3201], [3202], [3203], [3204], [3205], [3206], [3207], [3208], [3209], [3210], [3211], [3212], [3213], [3214], [3215], [3216], [3217], [3218], [3219], [3220], [3221], [3222], [3223], [3224], [3225], [3226], [3228], [3229], [3230], [3231], [3233], [3234], [3236], [3239], [3240], [3246], [3247], [3251], [3252], [3255], [3256], [3259], [3261], [3263], [3264], [3266], [3268], [3270], [3276], [3277], [3278], [3279], [3280], [3281], [3282], [3283], [3284], [3285], [3286], [3287], [3288], [3289], [3290], [3291], [3292], [3293], [3294], [3295], [3296], [3297], [3298], [3299], [3300], [3301], [3305], [3308], [3310], [3313], [3318], [3321], [3322], [3323], [3326], [3330], [3331], [3335], [3336], [3337], [3339], [3340], [3344], [3345], [3348], [3349], [3351], [3352], [3353], [3354], [3355], [3356], [3357], [3358], [3359], [3360], [3361], [3362], [3363], [3364], [3365], [3366], [3367], [3368], [3369], [3370], [3371], [3372], [3373],

Introduction

Carotid artery stenosis (CAS), a significant contributor to ischemic stroke, necessitates careful consideration of treatment strategies, ranging from optimal medical therapy (OMT) to various revascularization procedures. The landscape of CAS management is continually evolving, driven by advancements in surgical techniques, endovascular interventions, and pharmacological agents. Decisions regarding treatment are complex, often balancing the risks of intervention against the benefits of stroke prevention, and are further complicated by patient-specific factors such as symptom status, anatomical considerations, and comorbidities [401, 109, 212]. This paper synthesizes recent findings to provide a comprehensive overview of current treatment modalities and their associated outcomes.

Aim

The aim of this paper is to systematically review and synthesize current research on carotid stenosis treatment, identifying key outcomes, comparative efficacies of different modalities, emerging techniques, and critical areas for future investigation.

Methods

Systematic review with multilayer AI research agent: keyword normalization, retrieval & structuring, and paper synthesis (see SAIMSARA About section for details).

- **Bias:** Qualitatively inferred from study design fields. Retrospective cohort studies and case series inherently carry a higher risk of selection and reporting bias compared to prospective cohort studies and randomized controlled trials (RCTs). Many studies lacked specified directionality or detailed follow-up periods, limiting certainty in long-term outcomes. Small sample sizes in case reports and some cohort studies also limit generalizability.

Results

4.1 Study characteristics

The included studies predominantly comprised cohort designs (prospective and retrospective), case series, and case reports, with a smaller number of randomized controlled trials. Populations ranged from patients with asymptomatic or symptomatic unilateral and bilateral carotid stenosis to those

with specific comorbidities like head and neck cancer survivors, severe aortic stenosis, or Moyamoya disease. Follow-up periods varied widely, from immediate post-procedure assessments (e.g., 24 hours, 30 days) to intermediate (e.g., 6 months, 1 year) and long-term observations (e.g., 5, 10, or 15.8 years).

4.2 Main numerical result aligned to the query

A meta-analysis of randomized controlled trials comparing carotid artery stenting (CAS) with carotid endarterectomy (CEA) found that stenting was associated with an increased risk of periprocedural stroke (relative risk, 1.49, 95% CI, 1.11 to 2.01; risk difference, 1.7%; 95% CI, 0.3 to 3.0) and a long-term stroke risk (relative risk, 1.36; 95% CI, 1.16 to 1.61) [1610]. Conversely, stenting showed a decreased risk of periprocedural myocardial infarction (relative risk, 0.47; 95% CI, 0.29 to 0.78; risk difference, -0.4%; 95% CI, -0.8% to 0.1%) [1610]. Other studies reported mixed findings, with some indicating no significant difference in stroke, myocardial infarction, or death between CEA and CAS [409, 721, 2087], while others favored CEA for stroke and death outcomes, particularly in symptomatic patients [505, 825, 1073, 1830, 2426]. The 30-day stroke or death rates ranged from 0.4% [533] to 4.1% [2788] for CEA, and from 1.6% [533] to 9.6% [1966] for CAS.

4.3 Topic synthesis

- **Comparative Efficacy of Revascularization Techniques:** Carotid endarterectomy (CEA) is often considered the gold standard, demonstrating superior outcomes in terms of stroke prevention compared to carotid artery stenting (CAS) in some symptomatic patient populations (e.g., 30-day stroke rate: 2.5% for CEA vs. 7.5% for CAS in symptomatic patients [1073]; OR 1.72 for death/stroke with endovascular vs. endarterectomy [1830]). However, CAS may offer a lower risk of myocardial infarction [1610] and cranial nerve injury [924, 2509].
- **Role of Medical Therapy:** Optimized medical therapy (OMT) is foundational for all patients with carotid stenosis, with ongoing debate regarding the added benefit of revascularization for asymptomatic or low-risk symptomatic stenosis [85, 109, 183, 516, 582, 600, 1118]. Statin treatment, for example, is associated with a lower risk of radiation-induced carotid stenosis progression [34] and can increase plaque GSM [564].
- **Emerging Endovascular Techniques and Adjuncts:** Transcarotid artery revascularization (TCAR) is gaining prominence, showing superior perioperative outcomes compared to transfemoral CAS (TFCAS), with significantly lower rates of stroke and death [87]. Intravascular lithotripsy (IVL) appears valuable for severely calcified lesions, achieving technical success and excellent stent expansion [18, 956]. Novel stents like the CGuard stent demonstrate safety and efficacy with low perioperative neurological events [333, 334, 836, 2126].

- **Inflammation, Biomarkers, and Risk Stratification:** Inflammatory processes play a role in CAS progression and treatment outcomes, evidenced by increased carotid perivascular adipose tissue (CPVAT) after surgery [1] and elevated Lp(a) levels associated with plaque ulceration [49]. Biomarkers like NGAL are elevated in type 2 diabetics with CAS and reduced by metformin [812]. Risk models incorporating intraplaque hemorrhage and stenosis degree aid in identifying high-risk patients [166, 680].
- **Hemodynamic and Anatomical Considerations:** Post-treatment anatomical and hemodynamic changes, including contralateral artery responses and wall shear stress (WSS) alterations, are critical for understanding outcomes [2, 179, 367]. Tandem lesions, complex anatomy (e.g., retropharyngeal ICA, kinking), and severe calcification pose unique challenges requiring tailored approaches [114, 155, 163, 18, 419, 1146].
- **Cognitive and Neurological Outcomes:** Carotid revascularization can improve attentional performance [58], cognitive function [372, 626, 1600, 2049, 2114], and retinal microcirculation [240, 399, 681] in CAS patients. However, procedures carry risks such as cerebral hyperperfusion syndrome (CHS) [390, 508, 834, 1352] and silent brain infarcts (SBIs) [427, 1529].
- **Special Patient Populations and Comorbidities:** Treatment decisions are influenced by age (e.g., CAS higher stroke/death risk in 75-79 years vs. CEA [394]), comorbidities (e.g., hypertension, diabetes [11, 143, 1528]), and prior radiation exposure for head and neck cancer [34, 151, 170, 388, 646, 940, 1062, 1075, 1235, 1240, 1397, 1398, 1724, 2028, 2834, 2864, 2942, 3128, 3335]. Disparities in revascularization rates exist based on gender, race, and ethnicity [134, 933].

Discussion

5.1 Principal finding

A meta-analysis of randomized controlled trials found that carotid artery stenting (CAS) was associated with an increased risk of periprocedural stroke (relative risk, 1.49, 95% CI, 1.11 to 2.01; risk difference, 1.7%; 95% CI, 0.3 to 3.0) and a long-term stroke risk (relative risk, 1.36; 95% CI, 1.16 to 1.61) compared to carotid endarterectomy (CEA) [1610].

5.2 Clinical implications

- **CEA Preference for Stroke Risk:** For symptomatic carotid stenosis, CEA remains a primary recommendation due to a generally lower risk of perioperative and long-term stroke compared to CAS [1610, 1830, 2426].

- **CAS for High-Risk Patients:** CAS can be a viable alternative for patients deemed high surgical risk for CEA, or in specific anatomical conditions, offering advantages like lower myocardial infarction risk [1610, 924] and reduced cranial nerve injury [924, 2509].
- **Importance of Medical Management:** Optimal medical therapy (OMT), including statins and antiplatelet agents, is crucial for all patients, with some studies suggesting it alone may be sufficient for certain asymptomatic or low-risk symptomatic cases [85, 183, 516, 582, 600, 1118].
- **TCAR as a Promising Option:** Transcarotid artery revascularization (TCAR) is emerging as a safe and effective treatment, showing superior perioperative outcomes compared to transfemoral CAS (TFCAS) and comparable prognosis to CEA, with lower MI and cranial nerve injury rates [87, 924, 1075].
- **Personalized Treatment Approach:** Treatment decisions should be individualized, considering patient age, symptom status, comorbidities (e.g., radiation-induced stenosis, concurrent cardiac disease), anatomical complexity, and risk of complications like hyperperfusion syndrome or restenosis [143, 394, 508, 569, 736, 1189].

5.3 Research implications / key gaps

- **Optimal Medical Therapy Efficacy:** Randomized trials are needed to define the best medical treatment and identify specific asymptomatic carotid stenosis patient subgroups who would benefit most from invasive treatment [109, 346, 882].
- **Long-term TCAR Outcomes:** Further randomized trials are required to fully investigate the long-term efficacy and safety of TCAR compared to established treatments like CEA and CAS [45].
- **Biomarkers for Risk Stratification:** Research into novel biomarkers (e.g., Lp(a), NGAL, BMP6, inflammatory markers) and advanced imaging (e.g., plaque vulnerability, WSS) is needed to improve personalized stroke risk prediction and guide treatment decisions [49, 104, 166, 215, 680, 812, 1021].
- **Cognitive and Quality of Life Outcomes:** Prospective studies should consistently evaluate the impact of different treatment modalities on long-term cognitive function, sleep quality, and health-related quality of life [9, 58, 372, 459, 626, 1032].
- **Management of Complex Lesions:** Further research is needed to optimize treatment strategies for complex carotid lesions, such as tandem occlusions, severely calcified plaques, radiation-induced stenosis, and those with unusual anatomical variants [18, 114, 155, 163, 419, 956, 1146].

5.4 Limitations

- **Heterogeneity of Studies** — Varied study designs, populations, and outcome measures limit direct comparability and meta-analysis of all reported metrics.
- **Lack of Long-Term Follow-up** — Many studies, particularly for newer techniques, lack extensive long-term follow-up data, hindering assessment of durability and late complications.
- **Inconclusive RCTs** — Some large randomized controlled trials (e.g., SPACE-2) were prematurely stopped or had inconclusive findings, limiting definitive comparisons between treatment strategies.
- **Reporting Bias** — Case series and reports may disproportionately highlight successful or novel interventions, potentially underrepresenting complications or less favorable outcomes.
- **Limited Generalizability** — Studies often focus on specific patient subgroups or settings, making it challenging to generalize findings to broader, diverse populations.

5.5 Future directions

- **Standardize Outcome Reporting** — Implement core outcome sets for stroke, cognitive function, and quality of life across all carotid stenosis trials.
- **Comparative Effectiveness Research** — Conduct large, pragmatic RCTs comparing TCAR, CAS, and CEA in diverse patient populations, including those with comorbidities.
- **Biomarker-Guided Trials** — Design trials that use advanced imaging and circulating biomarkers to stratify patients and tailor treatment allocation.
- **Longitudinal Cognitive Assessment** — Integrate comprehensive cognitive and neurological assessments into long-term follow-up for all carotid revascularization studies.
- **Develop AI Predictive Models** — Utilize machine learning to predict treatment outcomes, such as hyperperfusion syndrome and in-stent restenosis, based on patient and lesion characteristics.

Conclusion

A meta-analysis of randomized controlled trials found that carotid artery stenting (CAS) was associated with an increased risk of periprocedural stroke (relative risk, 1.49, 95% CI, 1.11 to 2.01; risk difference, 1.7%; 95% CI, 0.3 to 3.0) and a long-term stroke risk (relative risk, 1.36; 95% CI, 1.16 to 1.61) compared to carotid endarterectomy (CEA) [1610]. This finding, however, exists within a complex landscape of evidence, where optimal medical therapy remains fundamental, and emerging techniques like TCAR show promise, particularly for high-risk patients. The heterogeneity of studies, including variations in design and outcome reporting, limits the certainty of direct comparisons

across all modalities. Clinicians should continue to individualize treatment decisions based on patient-specific risk factors, symptom status, and anatomical considerations, while researchers prioritize large, well-designed comparative effectiveness trials to refine guidelines and improve patient outcomes.

References

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Figure 1. Publication-year distribution of included originals

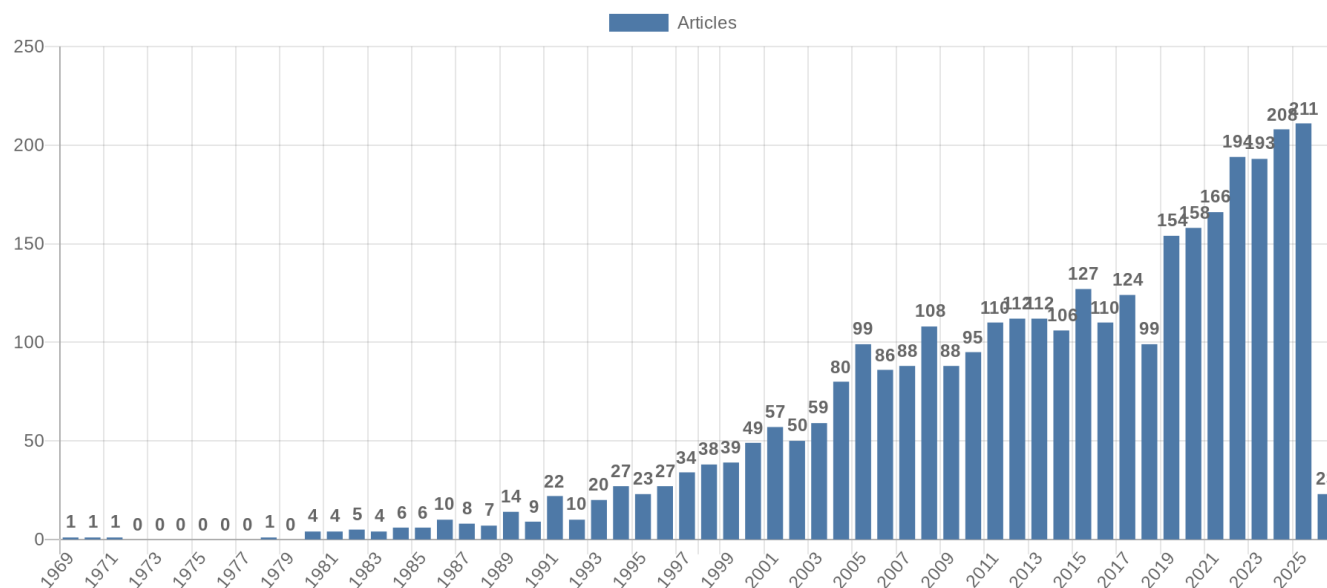


Figure 2. Study-design distribution of included originals

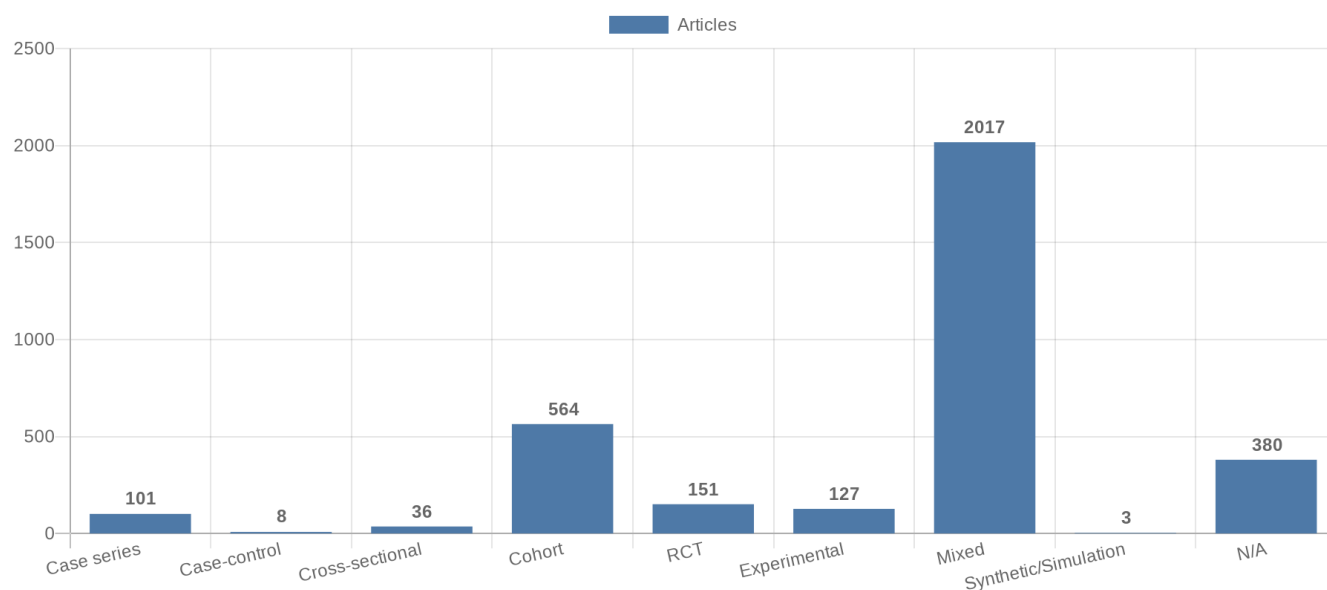


Figure 3. Study-type (directionality) distribution of included originals

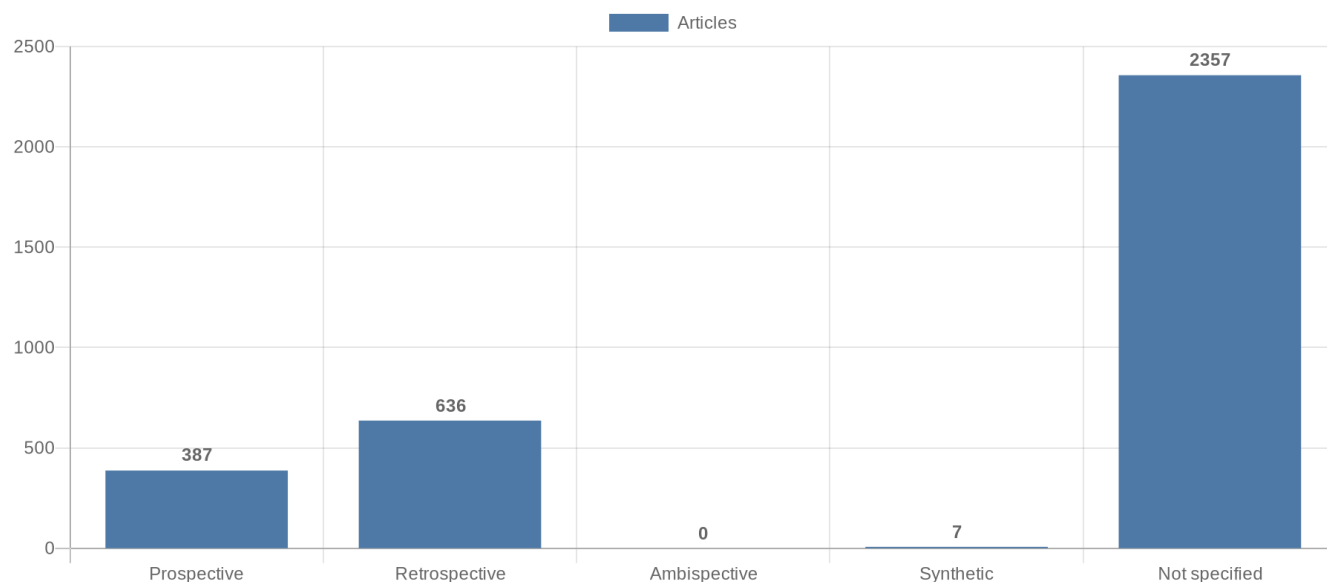


Figure 4. Main extracted research topics

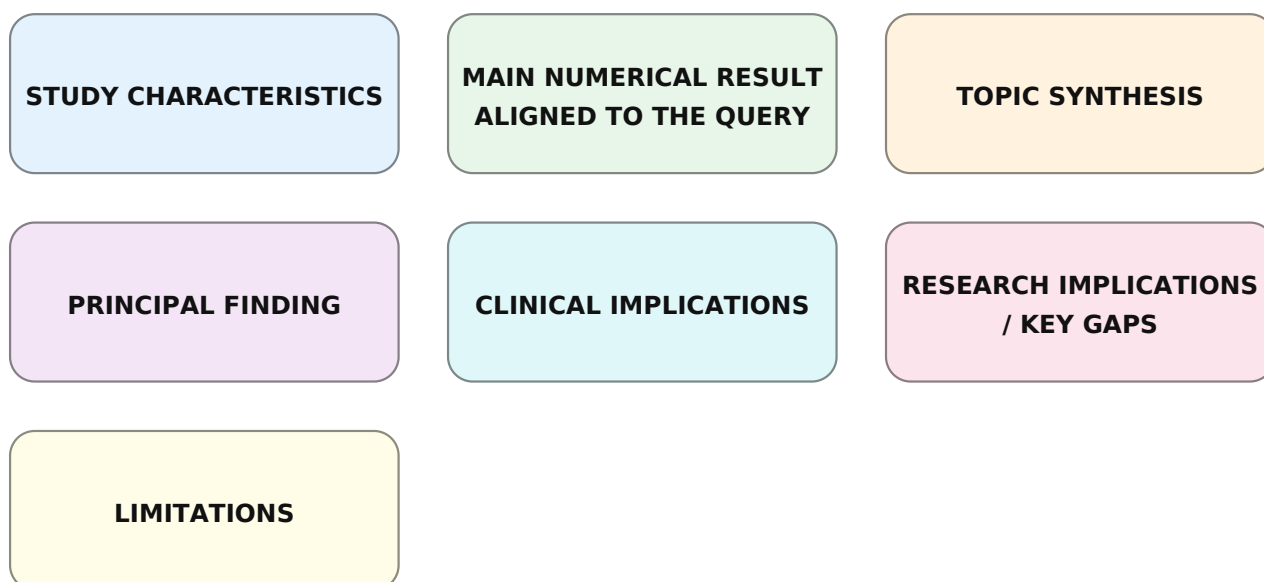


Figure 5. Limitations of current studies (topics)

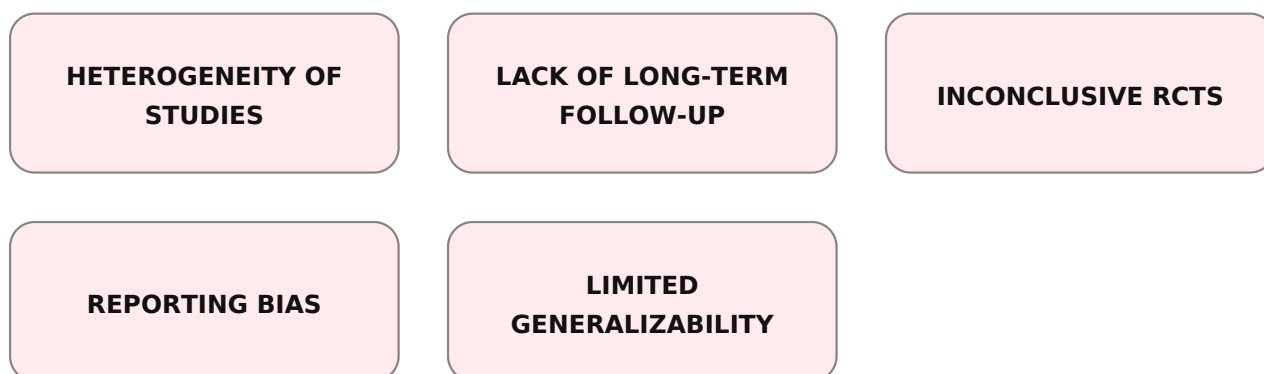


Figure 6. Future research directions (topics)

**OPTIMAL MEDICAL
THERAPY EFFICACY**

**LONG-TERM TCAR
OUTCOMES**

**BIOMARKERS FOR RISK
STRATIFICATION**

**COGNITIVE AND QUALITY
OF LIFE OUTCOMES**

**MANAGEMENT OF COMPLEX
LESIONS**

**STANDARDIZE OUTCOME
REPORTING**

**COMPARATIVE
EFFECTIVENESS RESEARCH**