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论著

# 人工智能辅助结肠镜检查对息肉检出率影响的 Meta分析

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摘要:目的 定量分析人工智能 (AI) 辅助结肠镜检查对息肉检出率的影响。方法 检索自建库至 2021年5月 Cochrane Library、PubMed、Embase、Web of Science、中国知网 (CNKI)、万方数据 (Wanfang Data) 和维普网 (VIP) 中关于AI辅助结肠镜检查的研究,并对文章进行质量评价,采用RevMan 5.4软件进行 Meta 分析。结果 纳入8篇文献,共6217例患者 (3095/3122)。与没有AI辅助的结肠镜检查相比,AI辅助结肠镜检查增加了腺瘤检出率 (ADR) (RR = 1.43,95%CI: 1.33~1.55, P=0.000),提高了息肉检出率 (PDR) (RR = 1.40,95%CI: 1.30~1.51, P=0.000)。左半结肠、右半结肠、 <10 mm 和无蒂的 ADR 和 PDR 明显增加 (P<0.01); AI 辅助结肠镜与常规结肠镜检查退镜观察时间无明显差异。结论 AI 辅助肠镜 检查可以增加腺瘤和息肉的检出率,与腺瘤及息肉的位置、大小及形态学相关,与退镜时间无关。 关键词:人工智能;结肠镜;息肉;腺瘤;深度学习;计算机辅助检测

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# Impact of artificial intelligence assisted colonoscopy on polyp detection rate: a Meta-analysis

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Abstract: Objective To make a quantitative analysis of the influence of artificial intelligence (AI) assisted colonoscopy on polyp detection. Methods As of May 2021, the research related to AI-assisted colonoscopy in Cochrane Library, PubMed, Embase, Web of Science, CNKI, Wanfang Data, and VIP were searched, and the quality of the articles was evaluated. RevMan 5.4 software was used for Meta-analysis. Results 8 literatures were included, including 6 217 cases (3 095/3 122). Compared with colonoscopy without AI, colonoscopy with AI increased the detection rate of adenoma (ADR) ( $\hat{R} = 1.43$ , 95%CI: 1.33 ~ 1.55, P = 0.000); Improved polyp detection rate (PDR) ( $\hat{R} = 1.40$ , 95%CI: 1.30~1.51, P = 0.000). ADR and PDR were significantly increased in left and right colon, <10 mm and pedunculated colon (P < 0.01); There was no significant difference in the observation time between AI assisted colonoscopy and routine colonoscopy. Conclusion AI assisted enteroscopy can increase the detection rate of adenomas and polyps, which is related to the location, size and morphology of adenomas and polyps, and has nothing to do with the time of withdrawal.

Keywords: artificial intelligence (AI); colonoscopy; polyps; adenoma; deep learning; computer-aided detection

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腺瘤性息肉已被证明是结直肠癌的癌前病变<sup>[1]</sup>, 结肠镜检查是目前发现并切除腺瘤性息肉的主要方法 之一[2],但结肠镜检查质量却有所差异。判断结肠镜 检查质量高低的指标分为术前质量指标(肠道准备)、 手术质量指标[盲肠插管率、退镜时间和腺瘤检出率 (adenoma detection rate, ADR) ]和术后质量指标(监 测间隔)<sup>3</sup>。虽然临床不断改进结肠镜检查的方法, 以提高检查质量,但结肠镜检查中的腺瘤漏诊率仍高 达27%<sup>[4]</sup>。人工智能 (artificial intelligence, AI) 已在 医学领域广泛应用,深度学习(deep learning, DL) 是一种机器学习方法,是AI应用领域的一个重要组 成部分<sup>[5]</sup>,在成像应用方面有着巨大的发展前景。DL 是应用神经网络结构的机器学习模式,与传统的机器 学习相比, DL拥有更强大的学习能力, 无需进行大 量数据的预处理和手动提取,即可自动提取特征,还 可进行多任务学习<sup>66</sup>。在医学成像方面,DL可应用于 病变检测及分类,同时进行辅助诊断,从而提高临床 工作的准确性和效率<sup>[7]</sup>。因此, DL模型在胃肠内镜检 查领域中发展迅速。最近的研究18表明,计算机辅助 检测(computer-aided detection, CADe)可以准确检 测大肠息肉,降低漏检率。但现有的研究在评估息肉 检测效能(如:息肉大小、形态、位置和组织学等) 上数据比较分散。为此,本研究系统总结了AI辅助 结肠镜对结直肠息肉检测率的影响,以及其与病变特 征之间的关系。

#### 1 资料和方法

## 1.1 文献检索策略

检索自建库至 2021 年 5 月 Cochrane Library、 PubMed、Embase、Web of Science、中国知网 (CNKI)、万方数据(Wanfang Data)和维普网(VIP) 中关于AI辅助结肠镜检查的研究。采用主题词与自 由词相结合的方法进行检索:artificial intelligence、 colonoscopes、colonoscopy、人工智能和结肠镜。

#### 1.2 纳入与排除标准

1.2.1 纳入标准 ①研究对象:行结肠镜检查的门 诊或住院患者,年龄≥18岁;②研究类型:随机对照 试验(randomized controlled trial, RCT);③干预措 施:AI组采用AI辅助结肠镜检查,对照组采用常规 结肠镜检查;④肠镜检查质量:波士顿肠道准备评估 量表(Boston bowel preparation scale, BBPS)≥6分, 退镜时间≥6min,盲肠插管率≥85%。

 1.2.2 排除标准 ①重复发表的文献; ②无全文、 信息不全或无法进行数据提取的文献; ③会议论文、 综述和个案报告; ④非中文或英文文献。

#### 1.3 结局指标

1.3.1 主要指标 ①ADR; ②息肉检出率 (polyp detection rate, PDR)。

1.3.2 次要指标 ①腺瘤位置(左半结肠、右半结肠); ②腺瘤大小(≤5 mm、6~9 mm和≥10 mm); ③
腺瘤形态(有蒂腺瘤和无蒂腺瘤); ④息肉位置(左半结肠和右半结肠); ⑤息肉大小(≤5 mm、6~9 mm和≥10 mm); ⑥息肉形态(有蒂息肉和无蒂息肉);
⑦退镜时间(不包括活组织检查或治疗时间)。

1.3.3 相关定义 结直肠息肉定义:任何已经切除并进行组织学检查的内镜下病变。腺瘤定义:组织学证实为腺瘤成分的息肉。

#### 1.4 文献筛选与资料提取

1.4.1 文献筛选 剔除重复文献后,依据纳入与排除标准进行文献筛选。由两名研究者根据纳入与排除标准,独立进行文献筛选、提取资料与核对,如遇分歧,则咨询第三方协助判断。文献筛选时,首先阅读文题和摘要,在排除明显不相关的文献后,进一步阅读全文,以确定是否纳入。

1.4.2 资料提取 主要包括:①文献的一般特征:第一作者、发表时间、国家、研究类型、样本量、性别和年龄;②结局指标;③文献质量评价。

#### 1.5 质量评价

由两名研究者按照Cochrane偏倚风险评估对纳入 的文献进行质量评价。对于RCT,评价标准包括:随 机序列产生、分配隐藏、实施者及研究者是否盲法、 研究结果盲法评价、不完整的数据结果、选择性报道 和其他偏倚等7项,每项均采用"是""否"和"不 清楚"进行评价,"是"为低度偏倚,"否"为高度偏 倚,"不清楚"为缺乏相关信息或偏倚情况不确定。

#### 1.6 统计学方法

采用 RevMan 5.4 软件进行 Meta 分析。二分类变 量采用相对危险度 RR值和95%CI计算;连续型变量 采用加权均数 WMD值和95%CI计算。P < 0.05 为差异 有统计学意义。结合  $I^2$ 和 P值进行异质性检验,若  $P > 0.1 或 I^2 < 50\%$ ,提示研究间异质性较小,采用固 定效应模型;若  $P < 0.1 和 I^2 > 50\%$ ,提示研究间异质 性较大,采用随机效应模型进行合并分析。

# 2 结果

## 2.1 文献检索结果及特征

在计算机上手动检索查询,共获得文献865篇, 逐层筛选后,最终纳入8篇<sup>19-16</sup>RCT,共6217例(AI 组3095例,对照组3122例),个体研究样本量为 669~1058例。文献筛选流程见图1。纳入研究的基 本特征见表1。

## 2.2 纳入文献的质量评价

8篇RCT偏倚风险评价中,1篇文献<sup>[10]</sup>未描述随 机序列产生的方法和分配隐藏;6篇文献<sup>[9-14]</sup>未对实 施者或参与者实施盲法,7篇文献<sup>[9-12,14-16]</sup>未对结局 指标实施盲法,8篇文献均无不完整数据及选择性报 道。见图2。

#### 2.3 主要结局Meta分析结果

2.3.1 ADR 纳入的8篇<sup>[9-16]</sup>研究均报道了ADR, 各研究间异质性小(P=0.090,  $I^2=43\%$ ),采用固 定效应模型分析。根据使用的AI系统,分为Wision AI系统和其他系统两个亚组。结果显示:AI组 的ADR均高于对照组(RR=1.43, 95%CI: 1.33~ 1.55, P=0.000);亚组分析中,Wision AI系统 (RR=1.31, 95%CI: 1.17~1.46, P=0.000)和其他 系统(RR=1.58, 95%CI: 1.41~1.77, P=0.000)的



ADR均高于对照组。见图3。敏感性分析:将随机效 应模型转换,并逐一去除每篇文献后,对异质性进行 检验,转换前后各项指标结果基本一致,表明 Meta 分析结果稳定。

2.3.2 PDR 纳入的 8 篇<sup>19-16</sup> 研究均报道了 PDR。 根据使用的 AI 系统,分为 Wision AI 系统和其他系统

#### 表1 纳入研究的基本特征 Table 1 Basic features of the included studies

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发表		日安	研究	样本	运量/例	性别(男/	平均年	耳龄/岁	NI I W
纳入又瞅	年份	<b>当</b> 豕	类型	AI组	对照组	女)/例	AI组	对照组	AI 糸坑
CONC <sup>[9]</sup>	2020年	山国	BCT	355	340	3/15/350	50	40	ENDOANGEL system
GONG	2020-4	1.12	ncı	555	549	545/559	50	49	(Wuhan, Hubei)
$I III = \Delta^{[10]}$	2020年	山国	BCT	508	518	551/475	51.02	50.13	CADe system(Henan Xuanweitang Medical
LIU A	2020		nor	500	510	5511475	51.02	50.15	Information Technology)
I III_B <sup>[11]</sup>	2020年	山国	RCT	303	307	374/416	10.84	48 70	CADe system EndoScreener
LIU-D	2020-4	1.12	ncı	393	591	574/410	49.04	40.79	(Wision AI, Shanghai)
REDICI <sup>[12]</sup>	2020年	音十利	RCT	3/1	344	337/3/8	61.5	61.1	CADe system
ILLI ICI	2020-4	总八州	ncı	541	544	5577540	01.5	01.1	(GI-Genius Medtronic)
SU[13]	2020年	山国	RCT	308	315	307/316	50.5	51.6	AQCS model
50	2020-4	1.12	ncı	508	515	5077510	50.5	51.0	(Jinan, Shandong)
WANG-A <sup>[14]</sup>	2019年	中国	RCT	522	536	512/546	51.07	49.94	Wision AI, Shanghai
WANC D <sup>[15]</sup>	2020年	山耳	PCT	101	179	405/467	40	40	CADe system EndoScreener
WANG-D	2020平	下国	NC1	404	470	495/407	49	49	(Wision AI, Shanghai)
WANC C <sup>[16]</sup>	o[16] 2020 /F	山耳	et por	19/	105	170/100	17 72	47 10	CADe system EndoScreener
WANG-C	2020年	中国	nul	164	185	1/9/190	41.12	47.19	(Wision AI, Shanghai)





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A:纳入研究的偏倚评估;"+"为低度偏倚,"-"为高度偏倚;B:柱状图 图 2 风险评估 Fig.2 Risk assessment

两个亚组。4项使用 Wision AI 系统的研究<sup>[11, 14-16]</sup> 异质性大(P=0.090,  $I^2=54\%$ ),采用随机效应 模型分析。结果显示:AI组的 PDR 均比对照组高 ( $\hat{R}R=1.40$ , 95%CI:1.30~1.51, P=0.000);亚组分 析中,Wision AI 系统( $\hat{R}R=1.38$ , 95%CI:1.22~ 1.55, P=0.000)和其他系统( $\hat{R}R=1.45$ , 95%CI: 1.31~1.61, P=0.000)的PDR高于对照组。见图4。 敏感性分析:将随机效应模型转换并逐一去除每篇文 献后,对异质性进行检验,转换前后各项指标结果基 本一致,表明 Meta分析结果稳定。

#### 2.4 次要结局Meta分析结果

2.4.1 腺瘤位置 共7篇文献<sup>[9-15]</sup>报道了腺瘤位置。
 各研究间异质性小 (P=0.230, I<sup>2</sup>=20%),采用固

定效应模型分析。根据腺瘤的位置,分为左半结肠腺瘤和右半结肠腺瘤两个亚组。结果显示:AI 组,左半结肠(RR=1.57,95%CI:1.42~1.73, P=0.000)和右半结肠(RR=1.72,95%CI:1.55~ 1.91,P=0.000)的ADR均高于对照组。见图5。 2.4.2 腺瘤大小 共6篇文献<sup>[9-12,14-15]</sup>报道了腺瘤 大小。根据腺瘤大小,分为<5 mm、6~9 mm 和 > 10 mm 3个亚组。6项腺瘤 < 5 mm的研究<sup>[9-12,14-15]</sup> 异质性大(P=0.040,  $I^2=57\%$ ),采用随机效应模 型分析。结果显示:AI组<10 mm的ADR均高于对 照组,即:<5 mm(RR=1.74,95%CI:1.52~1.99, P=0.000)和6~9 mm(RR=1.35,95%CI:1.08~ 1.69,P=0.008)的ADR均高于对照组,>10 mm

	Experim	ental	Contr	ol		Risk Ratio	Risk Ratio									
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% CI	M-H, Fixed, 95% Cl									
1.1.1 Wision AI系统																
Liu B 2020	114	393	83	397	11.3%	1.39 [1.08, 1.77]										
Wang A 2019	152	522	109	536	14.7%	1.43 [1.16, 1.77]										
Wang B 2020	165	484	134	478	18.5%	1.22 [1.01, 1.47]										
Wang C 2020	78	184	66	185	9.0%	1.19 [0.92, 1.54]										
Subtotal (95% CI)		1583		1596	53.6%	1.31 [1.17, 1.46]	•									
Total events	509		392													
Heterogeneity: Chi <sup>2</sup> = 2	2.01, df = 3	(P = 0.	57); l² = 0	%												
Test for overall effect:	Z = 4.72 (F	o < 0.000	001)													
1.1.2 其他系统																
Gong 2020	58	355	27	349	3.7%	2.11 [1.37, 3.25]										
Liu A 2020	198	508	123	518	16.7%	1.64 [1.36, 1.98]										
Repici 2020	187	341	139	344	19.0%	1.36 [1.16, 1.59]	<b>_</b>									
Su 2020	89	308	52	315	7.0%	1.75 [1.29, 2.37]										
Subtotal (95% CI)		1512		1526	46.4%	1.58 [1.41, 1.77]	•									
Total events	532		341													
Heterogeneity: Chi <sup>2</sup> = §	5.77, df = 3	(P = 0.7)	12); I <sup>2</sup> = 4	8%												
Test for overall effect:	Z = 8.03 (F	o < 0.000	001)													
Total (95% CI)		3095		3122	100.0%	1.43 [1.33, 1.55]										
Total events	1041		733													
Heterogeneity: Chi <sup>2</sup> =	12.19, df =	7 (P = 0	.09); I <sup>2</sup> =	43%												
Test for overall effect:	Z = 8.97 (F	<b>P</b> < 0.000	001)				Eavours [experimental] Eavours [control]									
Test for subaroup diffe	rences: Ch	ni² = 5.56	6. df = 1 (l	P = 0.0	2). $I^2 = 82$	Test for subgroup differences: Chi <sup>2</sup> = 5.56, df = 1 (P = 0.02), $l^2 = 82.0\%$										

#### 图 3 两组 ADR 比较的森林图

#### Fig.3 Forest plot of comparison of adenoma detection rate between the two groups

	Experim	ental	Contr	ol		Risk Ratio	Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% CI
2.1.1 Wision AI系统							
Liu B 2020	185	393	132	397	13.5%	1.42 [1.19, 1.69]	
Wang A 2019	235	522	156	536	15.0%	1.55 [1.31, 1.82]	
Wang B 2020	252	484	177	478	17.5%	1.41 [1.22, 1.63]	
Wang C 2020	117	184	102	185	14.1%	1.15 [0.97, 1.37]	+ <b>-</b> -
Subtotal (95% CI)		1583		1596	60.0%	1.38 [1.22, 1.55]	•
Total events	789		567				
Heterogeneity: Tau <sup>2</sup> =	0.01; Chi²	= 6.48, d	df = 3 (P =	= 0.09);	l² = 54%		
Test for overall effect:	Z = 5.23 (F	o < 0.000	001)				
2.1.2 其他系统							
Gong 2020	166	355	118	349	12.5%	1.38 [1.15, 1.66]	
Liu A 2020	221	508	144	518	14.0%	1.56 [1.32, 1.86]	
Repici 2020	68	341	57	344	5.0%	1.20 [0.88, 1.65]	
Su 2020	118	308	80	315	8.4%	1.51 [1.19, 1.91]	
Subtotal (95% CI)		1512		1526	40.0%	1.45 [1.31, 1.61]	$\bullet$
Total events	573		399				
Heterogeneity: Tau <sup>2</sup> =	0.00; Chi <sup>2</sup>	= 2.45, d	df = 3 (P =	= 0.48);	l² = 0%		
Test for overall effect: 2	Z = 6.99 (F	o < 0.000	001)				
Total (95% CI)		3095		3122	100.0%	1.40 [1.30, 1.51]	•
Total events	1362		966				
Heterogeneity: Tau <sup>2</sup> =	0.00; Chi <sup>2</sup>	= 9.46, d	df = 7 (P =	= 0.22);	l² = 26%		
Test for overall effect:	Z = 8.80 (F	o < 0.000	001)				U.3 U.7 I I.3 Z
Test for subaroup diffe	rences: Ch	$ni^2 = 0.44$	4. df = 1 (	P = 0.5	1). I² = 0%		

#### 图 4 两组 PDR 比较的森林图

Fig.4 Forest plot of comparison of polyp detection rate between the two groups

(RR = 1.39, 95%CI: 1.01~1.93, P=0.050)的 ADR 差异无统计学意义。见图6。

2.4.3 腺瘤形态 共5篇文献<sup>[10-11, 13-15]</sup>报道了腺瘤 形态。根据腺瘤形态,分为有蒂腺瘤和无蒂腺瘤两个亚 组。5项有蒂腺瘤的研究<sup>[10-11, 13-15]</sup>异质性小 (P=0.980, I<sup>2</sup>=0%),5项无蒂腺瘤的研究<sup>[10-11, 13-15]</sup>异质性小 (P=0.160, I<sup>2</sup>=39%),采用固定效应模型分析。结 果显示:AI组中无蒂的ADR高于对照组(RR=1.81, 95%CI: 1.66~1.98, P=0.000),AI组有蒂的ADR与 对照组相比,差异无统计学意义(RR=1.13,95%CI:0.89~1.43,P=0.330)。见图7。

2.4.4 息肉位置 纳入的6篇<sup>[9-11, 13-15]</sup>研究报道了 息肉位置。根据息肉位置,分为左半结肠息肉和 右半结肠息肉两个亚组。6项右半结肠息肉和 充<sup>[9-11, 13-15]</sup>异质性大 (*P*=0.005, *I*<sup>2</sup>=71%),采用 随机效应模型分析。结果显示: AI 组左半结 肠 (RR=1.68, 95%CI: 1.54~1.83, *P*=0.000)和右半 结肠 (RR=2.02, 95%CI: 1.73~2.36, *P*=0.000) 的PDR均高于对照组。见图8。

	Experime	ental	Contr	ol		Risk Ratio	Risk Ratio				
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% CI	M-H, Fixed, 95% Cl				
3.1.1 左半结肠腺瘤											
Gong 2020	26	355	10	349	1.1%	2.56 [1.25, 5.22]	· · · · · · · · · · · · · · · · · · ·				
Liu A 2020	131	508	81	518	8.7%	1.65 [1.29, 2.11]					
Liu B 2020	89	393	60	397	6.5%	1.50 [1.11, 2.02]					
Repici 2020	200	341	151	344	16.4%	1.34 [1.15, 1.55]					
Su 2020	48	308	18	315	1.9%	2.73 [1.62, 4.58]					
Wang A 2019	122	522	76	536	8.2%	1.65 [1.27, 2.14]					
Wang B 2020	132	484	85	478	9.3%	1.53 [1.20, 1.95]					
Subtotal (95% CI)		2911		2937	52.2%	1.57 [1.42, 1.73]	•				
Total events	748		481								
Heterogeneity: Chi <sup>2</sup> = 11.07, df = 6 (P = 0.09); l <sup>2</sup> = 46%											
Test for overall effect: 2	2 = 9.05 (P	< 0.000	001)								
3.1.2 右半结肠腺瘤											
Gong 2020	35	355	17	349	1.9%	2.02 [1.16, 3.54]					
Liu A 2020	119	508	61	518	6.6%	1.99 [1.50, 2.64]					
Liu B 2020	99	393	56	397	6.1%	1.79 [1.33, 2.40]					
Repici 2020	143	341	89	344	9.7%	1.62 [1.30, 2.02]					
Su 2020	65	308	38	315	4.1%	1.75 [1.21, 2.53]					
Wang A 2019	140	522	84	536	9.0%	1.71 [1.34, 2.18]					
Wang B 2020	149	484	96	478	10.5%	1.53 [1.23, 1.92]					
Subtotal (95% CI)		2911		2937	47.8%	1.72 [1.55, 1.91]	•				
Total events	750		441								
Heterogeneity: Chi <sup>2</sup> = 2	.71, df = 6	(P = 0.8)	34); I <sup>2</sup> = 0	%							
Test for overall effect: 2	2 = 10.16 (	P < 0.00	0001)								
Total (95% CI)		5822		5874	100.0%	1.64 [1.53, 1.76]	•				
Total events	1498		922								
Heterogeneity: Chi <sup>2</sup> = 1	6.35, df =	13 (P =	0.23); l² =	= 20%							
Test for overall effect: 2	2 = 13.59 (	P < 0.00	Favours [experimental] Favours [control]								
Test for subaroup differ	ences: Ch	i² = 1.49	). df = 1 (	P = 0.2	2). I <sup>2</sup> = 33.	.1%					

#### 图 5 两组不同位置 ADR 比较的森林图

## Fig.5 Forest plot of comparison of ADR at different locations polyp detection rate between the two groups

	Experim	ental	Contr	ol		Risk Ratio	Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI	M-H, Random, 95% Cl
3.2.1 ≤5mm							
Gong 2020	46	355	25	349	4.3%	1.81 [1.14, 2.88]	
Liu A 2020	166	508	89	518	10.3%	1.90 [1.52, 2.39]	
Liu B 2020	146	393	69	397	9.4%	2.14 [1.66, 2.74]	
Repici 2020	234	341	164	344	14.3%	1.44 [1.26, 1.64]	
Wang A 2019	185	522	102	536	10.9%	1.86 [1.51, 2.30]	
Wang B 2020	211	484	128	478	12.2%	1.63 [1.36, 1.95]	
Subtotal (95% CI)		2603		2622	61.5%	1.74 [1.52, 1.99]	•
Total events	988		577				
Heterogeneity: Tau <sup>2</sup> = 0	0.02; Chi <sup>2</sup>	= 11.75,	df = 5 (P	= 0.04	); I <sup>2</sup> = 57%		
Test for overall effect: 2	z = 8.07 (F	° < 0.000	001)				
3.2.2 6~9 mm							
Gong 2020	4	355	1	349	0.3%	3.93 [0.44, 35.01]	
Liu A 2020	63	508	43	518	6.0%	1.49 [1.03, 2.16]	
Liu B 2020	37	393	41	397	5.0%	0.91 [0.60, 1.39]	
Repici 2020	55	341	28	344	4.9%	1.98 [1.29, 3.05]	
Wang A 2019	61	522	50	536	6.4%	1.25 [0.88, 1.78]	
Wang B 2020	60	484	46	478	6.2%	1.29 [0.90, 1.85]	
Subtotal (95% CI)		2603		2622	28.7%	1.35 [1.08, 1.69]	◆
Total events	280		209				
Heterogeneity: Tau <sup>2</sup> = 0	0.03; Chi <sup>2</sup>	= 7.84, c	df = 5 (P =	= 0.17);	l² = 36%		
Test for overall effect: 2	z = 2.65 (F	P = 0.008	3)				
3.2.3 ≥10 mm							
Gong 2020	1	355	1	349	0.2%	0.98 [0.06, 15.66]	· · · · · · · · · · · · · · · · · · ·
Liu A 2020	21	508	10	518	2.0%	2.14 [1.02, 4.50]	
Liu B 2020	5	393	6	397	0.8%	0.84 [0.26, 2.74]	
Repici 2020	31	341	28	344	4.0%	1.12 [0.69, 1.82]	
Wang A 2019	16	522	8	536	1.6%	2.05 [0.89, 4.76]	
Wang B 2020	10	484	7	478	1.3%	1.41 [0.54, 3.68]	
Subtotal (95% CI)		2603		2622	9.8%	1.39 [1.01, 1.93]	
Total events	84		60				
Heterogeneity: Tau <sup>2</sup> = 0	0.00; Chi <sup>2</sup>	= 3.66, d	df = 5 (P =	= 0.60);	l² = 0%		
Test for overall effect: 2	z = 1.99 (F	<b>P</b> = 0.05)					
Total (95% CI)		7809		7866	100.0%	1.59 [1.42, 1.78]	•
Total events	1352		846				
Heterogeneity: Tau <sup>2</sup> = 0	0.02; Chi <sup>2</sup>	= 28.37.	df = 17 (	P = 0.0	4); l <sup>2</sup> = 40%	6	
Test for overall effect: Z	z = 8.18 (F	<pre>&gt; &lt; 0.000</pre>	)01)				U.2 U.5 1 2 5
Test for subaroup differ	ences: Ch	ni² = 4.37	7. df = 2 (	P = 0.1	1). I² = 54.2	2%	Favours [experimental] Favours [control]

## 图 6 两组不同大小ADR比较的森林图

Fig.6 Forest plot of comparison of ADR in different sizes between the two groups

	E		0			Dist. Datis	Disk Datis
Cturlu an Curl and	Experim	ental	Contr	OI	10/-1-1-4		
Study or Subgroup	Events	Total	Events	Total	weight	MI-H, FIXed, 95% C	MI-H, FIXed, 95% CI
3.3.1 有帝厭瘤							
Liu A 2020	40	508	36	518	5.5%	1.13 [0.73, 1.75]	
Liu B 2020	19	393	17	397	2.6%	1.13 [0.60, 2.14]	
Su 2020	15	308	13	315	2.0%	1.18 [0.57, 2.44]	
Wang A 2019	39	522	33	536	5.0%	1.21 [0.78, 1.90]	
Wang B 2020	19	484	20	478	3.1%	0.94 [0.51, 1.74]	
Subtotal (95% CI)		2215		2244	18.2%	1.13 [0.89, 1.43]	
Total events	132		119				
Heterogeneity: Chi <sup>2</sup> = 0	0.46, df = 4	(P = 0.9)	$98$ ); $I^2 = 0$	%			
Test for overall effect: 2	Z = 0.97 (P	e = 0.33)					
3.3.2 无蒂腺瘤							
Liu A 2020	210	508	106	518	16.2%	2.02 [1.66, 2.46]	
Liu B 2020	169	393	97	397	14.9%	1.76 [1.43, 2.16]	
Su 2020	98	308	43	315	6.6%	2.33 [1.69, 3.22]	
Wang A 2019	223	522	127	536	19.3%	1.80 [1.50, 2.16]	
Wang B 2020	257	484	160	478	24.8%	1.59 1.36, 1.851	
Subtotal (95% CI)		2215		2244	81.8%	1.81 [1.66, 1.98]	•
Total events	957		533				
Heterogeneity: Chi <sup>2</sup> = 6	6.55. df = 4	(P = 0.7)	16): I <sup>2</sup> = 3	9%			
Test for overall effect: 2	z = 13.36 (	P < 0.00	0001)				
Total (95% CI)		4430		4488	100.0%	1.69 [1.56, 1.83]	•
Total events	1089		652				
Heterogeneity: $Chi^2 = 1$	9.58 df =	9(P = 0)	$(02) \cdot l^2 =$	54%			· · · · · · · · · · · · · · · · · · ·
Test for overall effect:	7 = 12.49	P < 0.00	0.02, 1 = 0.001	0.70			0.2 0.5 1 2 5
Tost for subgroup diffor	= 12.49 (	$i^2 - 12.0$	36 df = 1	(P - 0)	0003) 18 -	02 5%	Favours [experimental] Favours [control]
restion subdroub alme	rences: Ch	n = 13.3	50. uf = 1	r = 0.	00031. 1~ =	92.070	

#### 图 7 两组不同形态 ADR 比较的森林图

#### Fig.7 Forest plot of comparison of ADR with different morphology between the two groups

	Experim	ental	Contr	ol		Risk Ratio	Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl	M-H, Random, 95% Cl
4.1.1 左半结肠息肉							
Gong 2020	127	355	93	349	7.8%	1.34 [1.07, 1.68]	
Liu A 2020	268	508	152	518	10.0%	1.80 [1.54, 2.10]	
Liu B 2020	171	393	90	397	8.1%	1.92 [1.55, 2.38]	
Su 2020	102	308	62	315	6.4%	1.68 [1.28, 2.21]	
Wang A 2019	286	522	174	536	10.4%	1.69 [1.46, 1.95]	
Wang B 2020	207	484	127	478	9.1%	1.61 [1.34, 1.93]	
Subtotal (95% CI)		2570		2593	51.7%	1.68 [1.54, 1.83]	•
Total events	1161		698				
Heterogeneity: Tau <sup>2</sup> =	0.00; Chi² :	= 6.31, c	if = 5 (P =	= 0.28);	l² = 21%		
Test for overall effect: 2	Z = 11.69 (	P < 0.00	001)				
4.1.2 右半结肠息肉							
Gong 2020	131	355	75	349	7.2%	1.72 [1.35, 2.19]	
Liu A 2020	218	508	96	518	8.3%	2.32 [1.88, 2.85]	
Liu B 2020	250	393	114	397	9.4%	2.22 [1.87, 2.63]	
Su 2020	75	308	34	315	4.4%	2.26 [1.55, 3.28]	
Wang A 2019	212	522	95	536	8.2%	2.29 [1.86, 2.83]	
Wang B 2020	294	484	181	478	10.7%	1.60 [1.40, 1.84]	
Subtotal (95% CI)		2570		2593	48.3%	2.02 [1.73, 2.36]	
Total events	1180		595				
Heterogeneity: Tau <sup>2</sup> =	0.03; Chi <sup>2</sup> :	= 16.95,	df = 5 (P	= 0.00	5); I² = 71%	6	
Test for overall effect: 2	Z = 8.90 (P	< 0.000	001)				
Total (95% CI)		5140		5186	100.0%	1.83 [1.66, 2.01]	•
Total events	2341		1293				
Heterogeneity: Tau <sup>2</sup> =	0.02; Chi <sup>2</sup> :	= 30.30,	df = 11 (	P = 0.0	$(01); I^2 = 64$	%	
Test for overall effect:	Z = 12.53 (	P < 0.00	)001)				
Test for subaroup diffe	rences: Ch	i² = 4.24	. df = 1 (	P = 0.0	4). $I^2 = 76.4$	1%	Favours [experimental] Favours [control]

#### 图 8 两组不同位置 PDR 比较的森林图

#### Fig.8 Forest plot of comparison of PDR at different locations between the two groups

2.4.5 息肉大小 共5篇文献<sup>[9-11, 14-15]</sup>报道了息肉 大小。。根据息肉大小,分为  $\leq$  5 mm、6~9 mm 和  $\geq$  10 mm 3 个亚组。5项息肉  $\leq$  5 mm的研究<sup>[9-11, 14-15]</sup> 异质性大 (*P*=0.000, *I*<sup>2</sup>=88%),采用随机效应模 型分析。结果显示: AI组 < 10 mm 的 PDR 高于对照 组,即:  $\leq$  5 mm (RR = 1.96, 95%CI: 1.65~2.32, *P*=0.000)和6~9 mm (RR = 1.30, 95%CI: 1.11~ 1.52, *P*=0.000)的PDR均高于对照组,两组  $\geq$  10 mm (RR = 1.36, 95%CI: 0.92~2.01, *P*=0.120)的PDR 比较,差异无统计学意义。见图9。

2.4.6 息肉形态 共5篇文献[10-11, 13-15]报道了息肉

形态。根据息肉形态,分为有蒂息肉和无蒂息肉两个 亚组。5项无蒂息肉的研究<sup>[10-11,13-15]</sup>异质性大 (*P*=0.002, *I*<sup>2</sup>=79%),采用随机效应模型分析。结 果显示:AI组中无蒂的PDR高于对照组(RR=1.92, 95%CI: 1.69~2.18, *P*=0.000),两组有蒂的PDR比 较,差异无统计学意义(RR=1.24,95%CI: 0.99~ 1.54, *P*=0.060)。见图10。

2.4.7 退镜时间 共6篇文献<sup>[9-11, 13-15]</sup>报道了退镜时间。各研究<sup>[9-11, 13-15]</sup>间异质性大(P=0.000, I<sup>2</sup>=93%),采用随机效应模型分析。结果显示:AI 组与对照组的退镜时间无差异(MD=0.27, 95%CI: -0.01~0.55, P=0.060)。见图11。

	Experime	ental	Contr	ol		Risk Ratio	Ris	sk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight I	<u>M-H, Random, 95% Cl</u>	M-H, Ra	ndom, 95% Cl
4.2.1 <b>≤</b> 5mm								
Gong 2020	158	355	114	349	10.0%	1.36 [1.13, 1.65]		
Liu A 2020	378	508	169	518	10.9%	2.28 [1.99, 2.61]		-
Liu B 2020	359	393	149	397	11.0%	2.43 [2.14, 2.77]		
Wang A 2019	399	522	198	536	11.1%	2.07 [1.83, 2.33]		-
Wang B 2020	406	484	228	478	11.4%	1.76 [1.59, 1.95]		-
Subtotal (95% CI)		2262		2278	54.5%	1.96 [1.65, 2.32]		•
Total events	1700		858					
Heterogeneity: Tau <sup>2</sup> = (	0.03; Chi <sup>2</sup> =	= 34.46,	df = 4 (P	< 0.00	001); I <sup>2</sup> = 88	1%		
Test for overall effect: 2	z = 7.67 (P	o < 0.000	001)					
4.2.2 6~9mm								
Gong 2020	9	355	7	349	2.0%	1.26 [0.48, 3.36]		
Liu A 2020	86	508	63	518	8.1%	1.39 [1.03, 1.88]		
Liu B 2020	56	393	47	397	7.1%	1.20 [0.84, 1.73]		
Wang A 2019	83	522	61	536	8.0%	1.40 [1.03, 1.90]		
Wang B 2020	84	484	69	478	8.2%	1.20 [0.90, 1.61]		
Subtotal (95% CI)		2262		2278	33.3%	1.30 [1.11, 1.52]		•
Total events	318		247					
Heterogeneity: Tau <sup>2</sup> = 0	0.00; Chi² =	= 0.86, d	df = 4 (P =	= 0.93);	$I^2 = 0\%$			
Test for overall effect: 2	z = 3.33 (P	P = 0.000	)9)					
4.2.3 <b>≥10mm</b>								
Gong 2020	11	355	3	349	1.3%	3.60 [1.01, 12.81]		
Liu A 2020	22	508	16	518	3.8%	1.40 [0.75, 2.64]	-	
Liu B 2020	6	393	8	397	1.7%	0.76 [0.27, 2.16]		
Wang A 2019	16	522	10	536	2.8%	1.64 [0.75, 3.59]	-	
Wang B 2020	11	484	11	478	2.6%	0.99 [0.43, 2.26]		
Subtotal (95% CI)		2262		2278	12.2%	1.36 [0.92, 2.01]		
Total events	66		48					
Heterogeneity: Tau <sup>2</sup> = (	0.01; Chi² =	= 4.29, d	df = 4 (P =	= 0.37);	l² = 7%			
Test for overall effect: 2	z = 1.54 (P	e = 0.12)						
Total (95% CI)		6786		6834	100.0%	1.63 [1.40, 1.89]		
Total events	2084		1153					
Heterogeneity: Tau <sup>2</sup> = 0	0.05; Chi² =	= 69.39,	df = 14 (	P < 0.0	0001); I <sup>2</sup> = 8	80%	01 02 05	1 2 5 10
Test for overall effect: 2	z = 6.38 (P	o < 0.000	001)				Favours [experimenta	I] Favours [control]
Test for subaroup differ	ences: Ch	$i^2 = 12.5$	50. df = 2	(P = 0.	002). $I^2 = 84$	.0%		

#### 图 9 两组不同大小PDR比较的森林图



	Experim	ental	Contr	ol		Risk Ratio	Risk Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% C	M-H, Random, 95% Cl
4.3.1 有蒂息肉							
Liu A 2020	52	508	36	518	7.2%	1.47 [0.98, 2.21]	
Liu B 2020	22	393	18	397	3.9%	1.23 [0.67, 2.27]	
Su 2020	18	308	15	315	3.3%	1.23 [0.63, 2.39]	
Wang A 2019	49	522	38	536	7.2%	1.32 [0.88, 1.99]	
Wang B 2020	23	484	28	478	4.8%	0.81 [0.47, 1.39]	
Subtotal (95% CI)		2215		2244	26.4%	1.24 [0.99, 1.54]	$\bullet$
Total events	164		135				
Heterogeneity: Tau <sup>2</sup> = 0	0.00; Chi <sup>2</sup>	= 3.19, c	df = 4 (P =	= 0.53);	$I^2 = 0\%$		
Test for overall effect: 2	Z = 1.88 (F	P = 0.06)					
4.3.2 无蒂息肉							
Liu A 2020	434	508	212	518	19.3%	2.09 [1.87, 2.33]	
Liu B 2020	398	393	182	397		Not estimable	
Su 2020	159	308	81	315	14.0%	2.01 [1.62, 2.49]	
Wang A 2019	449	522	231	536	19.6%	2.00 [1.80, 2.21]	
Wang B 2020	473	484	279	478	20.7%	1.67 [1.55, 1.81]	
Subtotal (95% CI)		2215		2244	73.6%	1.92 [1.69, 2.18]	•
Total events	1913		985				
Heterogeneity: Tau <sup>2</sup> = 0	0.01; Chi <sup>2</sup>	= 14.62,	df = 3 (P	= 0.00	2); $I^2 = 79^6$	%	
Test for overall effect: 2	z = 10.19 (	P < 0.00	0001)				
			,				
Total (95% CI)		4430		4488	100.0%	1.71 [1.50, 1.95]	•
Total events	2077		1120				
Heterogeneity: Tau <sup>2</sup> = (	0.02: Chi <sup>2</sup>	= 29.44.	df = 8 (P	= 0.00	$(03): 1^2 = 73$	3%	
Test for overall effect: 2	7 = 7.92 (F	< 0.000	001)		,,		0.2 0.5 1 2 5
Test for subaroup differ	ences: Ch	$i^2 = 11.5$	56. $df = 1$	(P = 0.	$0007$ ), $l^2 =$	91.3%	⊢avours [experimental] Favours [control]

#### 图 10 两组不同形态 PDR 比较的森林图

## Fig.10 Forest plot of comparison of PDR with different morphology between the two groups

	Expe	rimen	tal	с	Control		Control			Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV. Random, 95% C	IV, Random, 95% Cl		
Gong 2020	6.38	2.48	355	4.76	2.54	349	13.9%	1.62 [1.25, 1.99]	►		
Liu A 2020	6.16	1.26	508	6.11	1	518	17.7%	0.05 [-0.09, 0.19]	- <b>-</b>		
Liu B 2020	6.71	1.63	393	6.62	1.22	397	16.9%	0.09 [-0.11, 0.29]			
Su 2020	5.41	1.45	308	5.54	1.36	315	16.6%	-0.13 [-0.35, 0.09]			
Wang A 2019	6.18	1.11	522	6.07	1.38	536	17.5%	0.11 [-0.04, 0.26]			
Wang B 2020	6.48	1.32	484	6.37	1.09	478	17.5%	0.11 [-0.04, 0.26]			
Total (95% CI)			2570			2593	100.0%	0.27 [-0.01, 0.55]			
Heterogeneity: Tau <sup>2</sup> =	0.11; Ch	ni² = 68	.83, df	= 5 (P <	< 0.000	001); I²					
Test for overall effect:	Z = 1.87	(P = 0	.06)						Favours [experimental] Favours [control]		

#### 图 11 两组退镜时间比较的森林图

Fig.11 Forest plot of comparison of exit time between the two groups

## 2.5 发表偏倚

采用漏斗图评估发表偏倚,结果显示:主要结局 指标中的ADR和PDR漏斗图左右基本对称,提示发 表偏倚较小。次要结局指标中的腺瘤大小、腺瘤位



置、腺瘤形态、息肉大小、息肉位置和息肉形态漏 斗图左右不对称,提示有一定的偏倚;退镜时间漏 斗图左右基本对称,提示发表偏倚较小。见图12 和13。



A:ADR;B:PDR 图 12 主要结局指标漏斗图





A:腺瘤大小;B:腺瘤位置;C:腺瘤形态;D:息肉大小;E:息肉位置;F:息肉形态;G:退镜时间

图 13 次要结局指标漏斗图

Fig.13 Funnel plot of secondary outcome indicators

## 3 讨论

## 3.1 结直肠癌的临床现状

结直肠癌是全球第三大常见癌症,其发病率在逐年上升<sup>[17-18]</sup>,结肠镜检查是公认的最有效的筛查方法之一<sup>[19]</sup>。目前,结肠镜检查质量在不断提高,但腺瘤漏诊时有发生,主要原因有:内镜医师的注意力或识别能力有差异,进镜过程中未完全暴露结直肠黏膜,腺瘤切除不完全<sup>[20-21]</sup>等。虽然黏膜暴露取决于内镜医师的检查技术、肠道准备的质量和内镜本身的旋转角度,但可以通过AI辅助来改善息肉在内镜屏幕上可见却不能识别的问题。AI系统可以根据图像之间的特征差异来识别病变,并对图像进行快速处理<sup>[6]</sup>,可以在内镜检查期间实时使用<sup>[22]</sup>。因此,AI系统可以在内镜检查期间标记可疑区域,从而辅助内镜医生识别息肉。

## 3.2 AI辅助的结肠镜检查

本文共纳入8篇RCT, Meta分析结果显示: AI辅助结肠镜检查提高了ADR和PDR;次要结果中,AI 组与对照组相比,腺瘤和息肉的检出率与位置、大小 和形态相关。AI组 < 10 mm 腺瘤和息肉的检出率提 高,考虑原因是:腺瘤和息肉直径越小,肉眼越不容 易观察到,利用AI可以帮助识别病变;无蒂腺瘤和 息肉的检出率增加,考虑原因为:无蒂的腺瘤和息肉 基底部较宽,呈扁平状,内镜医师肉眼不容易识别。 AI辅助可以弥补人眼的识别缺陷,增加检出率。此 外,两组患者的退镜观察时间比较,差异无统计学意 义。由此可见,即使用AI辅助结肠镜检查,亦不会 增加时间效率。

近年来,LIU等<sup>[11]</sup>、WANG等<sup>[14]</sup>、WANG等<sup>[15]</sup>和 WANG等<sup>[16]</sup>均使用 Shanghai Wision AI DL系统,结果 均显示:AI 辅助结肠镜检查增加了 ADR 和 PDR,且 有较高的灵敏度和特异度。REPICI等<sup>[23]</sup>报道了一项 前瞻性 RCT,该研究由 10名非资深的内镜医师(操 作 < 2 000例)使用 DL CADe 系统,将 660 名患者随 机分组,结果显示:CADe 能明显提高 ADR (53.3% 和 44.5%, *P* < 0.01),且 AI 辅助结肠镜的 PDR 稳定, 不受内镜医师的经验影响。

#### 3.3 AI的临床应用

AI在临床实践中实施时,还有许多问题需要解

决。AI和DL模型的算法仍在不断发展<sup>[24]</sup>,不同模型 和训练数据之间存在很大的差异,每个AI系统都需 要独立的前瞻性验证。将DL应用于结肠镜检查时, 仍然需要临床医生提供结肠镜诊断图像等临床数据, 再让机器学习,最后才可做出诊断<sup>[5,25]</sup>,可能会因无 法识别系统中未包含的疾病亚型而导致漏诊,也有可 能因数据不足,将较为罕见的疾病亚型识别为疾病常 态,从而导致误诊的发生<sup>[26]</sup>。DL亦无法识别出新的 病种,且DL依赖于高质量的图像数据,若患者肠道 准备不足,或有出血灶等导致图像清晰度较低时,则 可能无法准确识别<sup>[27]</sup>。因此,需完善统一各模型的数 据,增加数据库的储备,提高DL对图像的处理功能; 随着5G技术的普及以及与AI和大数据的结合,AI在 肠镜中的应用将更标准化和规范化。

#### 3.4 本研究的局限性

本研究具有一定的局限性。首先,纳入的部分研 究未提及随机分组和分配隐藏的方法,文献质量有待 提高;其次,部分文献的结局指标数据格式不统一, 可能导致 Meta分析产生偏倚,影响结果的可靠性。

综上所述,肠镜检查中应用AI辅助可以提高 PDR和ADR,与息肉和腺瘤的位置、大小及形态相 关,与退镜时间无关。

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