

人参二醇酰化产物的合成及其舒张血管活性评价^{*}

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摘要: **目的** 研究人参二醇衍生物及其舒张血管活性。**方法** 通过酰化反应合成人参二醇衍生物, 其结构均经过核磁共振、质谱确证, 再进行舒张血管活性评价。**结果** 合成 10 个人参二醇酰化产物, 均未见文献报道, 经舒张血管活性评价, 发现化合物 **1, 3, 4, 7** 具有一定的血管舒张活性。**结论** 筛选到 4 个衍生物有舒张血管活性, 这些化合物值得进一步研究。

关键词: 人参二醇; 舒张血管活性; 酰化产物

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Synthesis and Vasodilation Activity Evaluation of Acylated Panaxadiol Derivatives

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ABSTRACT: Objective To study the derivatives of Panaxadiol and its diastolic vaso activity. **Methods** Panaxadiol derivatives were synthesized by acylating reagents and cinnamyl acylating reagents, and their structures were confirmed by NMR and LC-MS. **Results** One Panaxadiol derivative and nine Panaxadiol cinnamic acid derivatives were synthesized, and none of them has been reported in the literature. Compounds **1, 3, 4, 7** was found to have certain vasodilatory activity. **Conclusion** Compounds with diastolic vasoactivity were screened, and these compounds deserve further study.

KEY WORDS: panaxadiol; vasodilation activity; acylated products

三七皂苷或人参皂苷是三七或人参的主要活性成分, 其主要具有抗肿瘤、免疫调节、抗炎镇痛等作用^[1], 其酸水解后水解产物之一为人参二醇^[2]。本课题组长期从事人参皂苷元类化合物的结构修饰, 已经制

备了较多的人参二醇或者人参三醇衍生物^[3-4], 脂肪酸类, 氨基酸类与人参二醇或者原人参二醇结合的衍生物中均有比人参二醇或者原人参二醇更有效的抗肿瘤活性化合物^[5-8]。本课题组前期经还原胺化反应

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将人参二醇降解产物的3位羰基转变成氨基,再与酰化试剂以及磺酰氯等试剂反应,得到一系列降解人参二醇的衍生物17个,采用MTS法对5株肿瘤细胞株进行活性评价,找到一些有细胞毒活性的化合物^[9]。肉桂酸(又名桂皮酸),是一种非常重要的植物源的自然产物,是从肉桂皮或安息香分离出的有机酸,肉桂酸及其衍生物具有抗老年痴呆^[10],抗结核^[11],抗菌^[12],抗氧化^[13],抗肿瘤^[14-15],抗心血管系统疾病^[16-17]等多种生物活性。本文通过人参二醇与酰氯或者肉桂酸(酰氯)试剂反应合成人参二醇衍生物或者人参二醇肉桂酸类衍生物,并且评价其舒张血管活性,期望找到一些舒张血管活性较好的化合物。

1 仪器与材料

AV-400核磁共振仪或AV-500核磁共振仪(德国Bruker公司);LCQ-Advantage LC-MS(Thermo Finnigan);RE-2000A旋转蒸发仪(上海亚荣生化仪器厂);FA2004电子天平(上海舜宇恒平科学仪器有限公司);DF-101S集热式恒温加热磁力搅拌器(巩义市予华仪器有限公司);KQ-100型超声清洗器(昆山市超声仪器有限公司);SHZ-D循环水式真空泵(巩义市予华仪器有限公司);Wire Myograph System DMT血管张力测定仪(Danish MyoTechnology)。

SD大鼠(昆明医科大学实验动物中心提供);GF254薄层层析板;柱层析用硅胶(青岛海洋化工厂);高效薄层层析板(默克);人参二醇(上海思达医药化工科技有限公司);化学合成试剂主要为优级纯,

少量分析纯,均购买于上海晶纯实业有限公司和上海泰坦科技股份有限公司。

2 方法与结果

2.1 化合物1的合成^[18] 在带有加热、搅拌、回流冷凝管等装置的25 mL二颈瓶中分别加入人参二醇50 mg,2,2-二甲基丁酰氯151.9 mg,DMAP 44 mg,吡啶8 mL,在常温下搅拌24 h。减压蒸干吡啶后,加入30 mL水后用乙酸乙酯萃取(100 mL×3),合并萃取液,用10%盐酸洗3次、饱和食盐水洗3次,无水Na₂SO₄干燥,过滤,滤液浓缩,硅胶(300-400目,石油醚:乙酸乙酯)柱色谱纯化得化合物1。白色粉末,收率60.7%;ESI-MS(*m/z*):560.4[M+H]⁺; ¹H NMR(400 MHz, CDCl₃) δ :0.83,0.85,0.86,0.88,0.90,0.97,1.13,1.15,1.17,1.21,1.26(33H, s, 11×CH₃),3.50-3.56(1H, m, CH-12),4.40-4.44(1H, m, CH-3); ¹³C NMR(CDCl₃, 100 MHz) δ :177.5(C-1'),80.2(C-3),76.6(C-20),73.1(C-25),69.9(C-12),55.8(C-5),54.6(C-17),51.1(C-14),49.7(C-9),49.0(C-13),42.8(C-2'),39.7(C-8),38.4(C-1),37.9(C-4),36.9(C-24),36.3(C-10),35.6(C-22),34.7(C-7),33.2(C-3'),32.9(C-27),31.0(C-15),30.4(C-11),27.9(C-26),27.0(C-29),25.1(C-2),24.9(C-16),19.3(C-21),18.1(C-6),17.0(C-30),16.5(C-23),16.2(C-18),16.1(C-19),15.5(C-28),9.2(C-4'')。

2.2 化合物2的合成 在带有加热、搅拌、回流冷凝管等装置的25 mL二颈瓶中分别加入人参二醇50

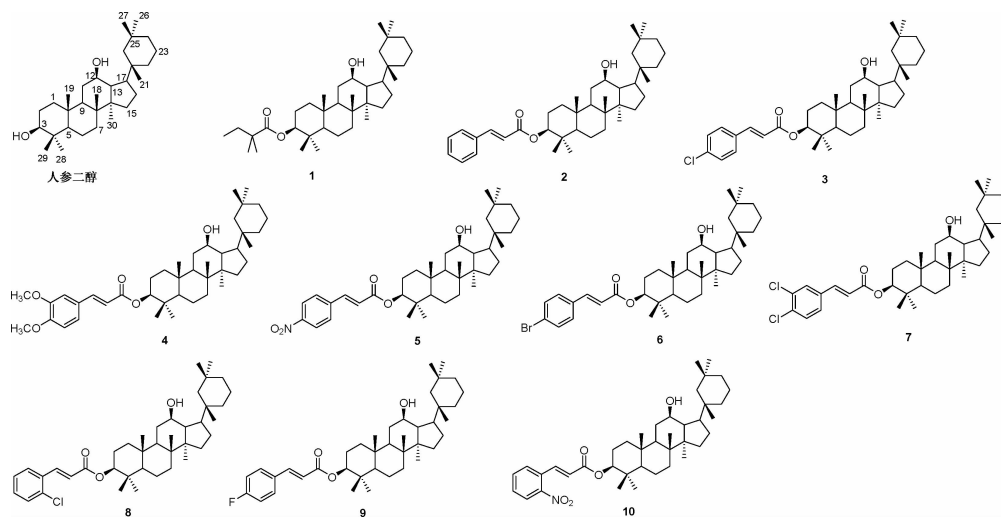


图1 人参二醇与化合物1-10的化学结构

mg, 肉桂酰氯 151.9 mg, DMAP, 44 mg, 吡啶 8 mL, 在常温下搅拌 24 h。减压蒸干吡啶后, 加入 30 mL 水后用乙酸乙酯萃取(100 mL×3), 合并萃取液, 用 10% 盐酸洗 3 次、饱和食盐水洗 3 次, 无水 Na_2SO_4 干燥, 过滤, 滤液浓缩, 硅胶(300–400 目, 石油醚: 乙酸乙酯)柱色谱纯化得化合物 **2** (23.5 mg)。白色粉末, 收率 36.2%; ESI-MS (m/z): 591.9 $[\text{M}+\text{H}]^+$; ^1H NMR (400 MHz, CDCl_3) δ : 0.89, 0.89, 0.93, 0.93, 1.18, 1.22, 1.26, 1.29 (24H, s, $8\times\text{CH}_3$), 3.52–3.58 (1H, m, CH-12), 4.60–4.64 (1H, m, CH-3), 6.44 (1H, d, $J=16.0$ Hz, CH-2'), 7.37–7.54 (4H, m, ArH), 7.66 (1H, d, $J=16.0$ Hz, CH-3'); ^{13}C NMR (CDCl_3 , 100 MHz) δ : 166.8 (C-1'), 144.2 (C-3'), 134.4 (Ar-C-1), 130.0 (Ar-C-4), 128.8 (Ar-C-3), 128.8 (Ar-C-5), 128.0 (Ar-C-2), 128.0 (Ar-C-6), 118.7 (C-2'), 80.8 (C-3), 76.6 (C-20), 73.1 (C-25), 69.9 (C-12), 55.9 (C-5), 54.6 (C-17), 51.1 (C-14), 49.7 (C-9), 49.0 (C-13), 39.7 (C-8), 38.5 (C-1), 38.0 (C-4), 37.0 (C-24), 36.3 (C-10), 35.6 (C-22), 34.7 (C-7), 32.9 (C-27), 31.0 (C-15), 30.4 (C-11), 28.0 (C-26), 27.0 (C-29), 25.1 (C-2), 23.7 (C-16), 19.3 (C-21), 18.1 (C-6), 16.9 (C-30), 16.6 (C-23), 16.2 (C-18), 16.1 (C-19), 15.5 (C-28).

2.3 化合物 3–10 的合成^[9] 在二颈反应瓶中加入人参二醇(1eq, 0.05 mmol)、肉桂酸衍生物(3eq, 0.15 mmol)和 10 mL CH_2Cl_2 , 搅拌使其充分溶解后, 加入过量 DCC 和少量 DMAP, 室温搅拌反应过夜。过滤, 滤液用饱和食盐水洗涤一次, 加入无水 Na_2SO_4 干燥, 再次过滤, 滤液减压浓缩, 硅胶(300–400 目, 石油醚: 乙酸乙酯)柱色谱纯化得到化合物 **3–10**。

化合物 **3** 白色粉末, 收率 40.8%; ESI-MS (m/z): 626.3 $[\text{M}+\text{H}]^+$; ^1H NMR (500 MHz, CDCl_3) δ : 0.88–1.26 (24H, s, $8\times\text{CH}_3$), 3.51–3.57 (1H, m, CH-12), 4.59–4.63 (1H, m, CH-3), 6.41 (1H, d, $J=16.0$ Hz, CH-2'), 7.26–7.47 (4H, m, ArH), 7.60 (1H, d, $J=16.0$ Hz, CH-3'); ^{13}C NMR (CDCl_3 , 125 MHz) δ : 166.5 (C-1'), 153.9 (C-3'), 142.7 (Ar-C-4), 141.9 (Ar-C-1), 132.9 (Ar-C-2), 132.9 (Ar-C-6), 129.1 (Ar-C-3), 129.0 (Ar-C-5), 119.8 (C-2), 81.0 (C-3), 76.6 (C-20), 73.1

(C-25), 69.8 (C-12), 55.9 (C-5), 54.6 (C-17), 51.1 (C-14), 49.7 (C-9), 49.0 (C-13), 39.7 (C-8), 38.5 (C-1), 38.0 (C-4), 37.0 (C-24), 36.3 (C-10), 35.6 (C-22), 34.7 (C-7), 32.9 (C-27), 31.0 (C-15), 30.9 (C-11), 28.0 (C-26), 27.1 (C-29), 26.2 (C-2), 23.7 (C-16), 19.3 (C-21), 18.1 (C-6), 16.9 (C-30), 16.6 (C-23), 16.2 (C-18), 16.1 (C-19), 15.5 (C-28).

化合物 **4** 白色粉末, 收率 60.2%; ESI-MS (m/z): 651.9 $[\text{M}+\text{H}]^+$; ^1H NMR (500 MHz, CDCl_3) δ : 0.88, 0.89, 0.93, 0.93, 0.98, 1.18, 1.22, 1.26 (24H, s, $8\times\text{CH}_3$), 3.53–3.57 (1H, m, CH-12), 4.60–4.63 (1H, m, CH-3), 6.30 (1H, d, $J=15.9$ Hz, CH-2'), 6.83–7.10 (3H, m, ArH), 7.60 (1H, d, $J=15.9$ Hz, CH-3'); ^{13}C NMR (CDCl_3 , 125 MHz) δ : 167.0 (C-1'), 150.9 (Ar-C-3), 149.0 (Ar-C-4), 144.1 (C-3'), 127.4 (Ar-C-1), 122.5 (Ar-C-6), 116.4 (C-2'), 110.8 (C-5'), 109.4 (C-2'), 80.6 (C-3), 76.6 (C-20), 73.1 (C-25), 70.0 (C-12), 55.9 (OCH₃), 55.9 (OCH₃), 55.8 (C-5), 54.6 (C-17), 51.1 (C-14), 49.7 (C-9), 49.0 (C-13), 39.7 (C-8), 38.5 (C-1), 38.0 (C-4), 37.0 (C-24), 36.3 (C-10), 35.6 (C-22), 34.7 (C-7), 32.9 (C-27), 31.0 (C-15), 30.4 (C-11), 28.0 (C-26), 27.0 (C-29), 25.1 (C-2), 23.8 (C-16), 19.3 (C-21), 18.1 (C-6), 16.9 (C-30), 16.6 (C-23), 16.2 (C-18), 16.1 (C-19), 15.5 (C-28).

化合物 **5** 淡黄色粉末, 收率 50.6%; ESI-MS (m/z): 636.9 $[\text{M}+\text{H}]^+$; ^1H NMR (500 MHz, CDCl_3) δ : 0.86–1.53 (24H, s, $8\times\text{CH}_3$), 3.52–3.58 (1H, m, CH-12), 4.62–4.66 (1H, m, CH-3), 6.13 (1H, d, $J=12.5$ Hz, CH-2'), 6.99 (1H, d, $J=12.5$ Hz, CH-3'), 7.68 (1H, d, $J=8.7$ Hz, CH-2" and 6"), 8.25 (1H, d, $J=8.7$ Hz, CH-3" and 5"); ^{13}C NMR (CDCl_3 , 125 MHz) δ : 166.2 (C-1'), 148.8 (Ar-C-4), 141.7 (C-3'), 141.1 (Ar-C-1), 129.0 (Ar-C-2), 129.0 (Ar-C-6), 124.5 (Ar-C-3), 124.2 (Ar-C-5), 123.6 (C-2'), 82.0 (C-3), 76.6 (C-20), 73.6 (C-25), 70.4 (C-12), 56.3 (C-5), 55.0 (C-17), 51.6 (C-14), 50.2 (C-9), 49.4 (C-13), 39.8 (C-8), 38.5 (C-1), 37.4 (C-4), 36.8 (C-24), 36.1 (C-10), 35.1 (C-22), 33.4 (C-7), 31.5 (C-27), 30.8 (C-15), 30.1 (C-11),

28.4(C-26), 27.5(C-29), 25.5(C-2), 23.4(C-16), 19.8(C-21), 18.6(C-6), 17.4(C-30), 17.0(C-23), 16.6(C-18), 16.0(C-19), 15.5(C-28).

化合物 6 白色粉末, 收率 19.5%; ESI-MS(m/z): 670.8[M+H]⁺; ¹H NMR(500 MHz, CDCl₃) δ : 0.87, 0.89, 0.92, 0.93, 0.97, 1.19, 1.23, 1.27 (24H, s, 8 $\times$ CH₃), 3.53–3.59(1H, m, CH-12), 4.09–4.14(1H, m, CH-3), 6.42 (1H, d, J =16.0 Hz, CH-2'), 7.39 (1H, d, J =8.4 Hz, CH-3" and 5"), 7.51(1H, d, J =8.4 Hz, CH-2" and 6"), 7.58 (1H, d, J =16.0 Hz, CH-3'); ¹³C NMR(CDCl₃, 125 MHz) δ : 166.5 (C-1'), 142.8 (C-3'), 133.5 (Ar-C-1), 132.0 (Ar-C-3), 132.0 (Ar-C-5), 129.3 (Ar-C-2), 129.3 (Ar-C-6), 124.3 (Ar-C-4), 119.6 (C-2'), 81.1 (C-3), 76.6 (C-20), 73.2 (C-25), 70.0 (C-12), 56.0 (C-5), 54.7 (C-17), 51.2 (C-14), 49.8 (C-9), 49.1 (C-13), 39.8 (C-8), 38.6 (C-1), 38.1 (C-4), 37.0 (C-24), 36.4 (C-10), 35.7 (C-22), 34.8 (C-7), 32.9 (C-27), 31.1 (C-15), 30.4 (C-11), 28.0 (C-26), 27.1 (C-29), 25.1 (C-2), 23.8 (C-16), 19.4 (C-21), 18.2 (C-6), 17.0 (C-30), 16.6 (C-23), 16.2 (C-18), 16.1 (C-19), 15.6 (C-28).

化合物 7 白色粉末, 收率 75.1%; ESI-MS(m/z): 660.8[M+H]⁺; ¹H NMR(500 MHz, CDCl₃) δ : 0.88, 0.88, 0.92, 0.92, 0.98, 1.18, 1.22, 1.26 (24H, s, 8 $\times$ CH₃), 3.52–3.58(1H, m, CH-12), 4.59–4.63(1H, m, CH-3), 6.42 (1H, d, J =16.0 Hz, CH-2'), 7.54 (1H, d, J =16.0 Hz, CH-3'), 7.33–7.61 (3H, m, ArH); ¹³C NMR(CDCl₃, 125 MHz) δ : 166.1 (C-1'), 141.4 (C-3'), 134.5 (Ar-C-1), 133.9 (Ar-C-3), 133.1 (Ar-C-4), 130.8 (Ar-C-5), 129.5 (Ar-C-2), 126.9 (Ar-C-6), 120.6 (C-2'), 81.2 (C-3), 76.6 (C-20), 73.2 (C-25), 70.0 (C-12), 55.9 (C-5), 54.6 (C-17), 51.1 (C-14), 49.7 (C-9), 49.0 (C-13), 39.7 (C-8), 38.5 (C-1), 38.0 (C-4), 37.0 (C-24), 36.3 (C-10), 35.6 (C-22), 34.7 (C-7), 32.9 (C-27), 31.0 (C-15), 30.4 (C-11), 28.0 (C-26), 27.0 (C-29), 25.1 (C-2), 23.7 (C-16), 19.3 (C-21), 18.1 (C-6), 16.9 (C-30), 16.5 (C-23), 16.2 (C-18), 16.1 (C-19), 15.5 (C-28).

化合物 8 白色粉末, 收率 58.3%; ESI-MS(m/z): 626.3[M+H]⁺; ¹H NMR(400 MHz, CDCl₃) δ : 0.89, 0.90, 0.93, 0.93, 0.99, 1.18, 1.22, 1.27 (24H, s, 8 $\times$ CH₃), 3.52–3.59(1H, m, CH-12), 4.60–4.64(1H, m, CH-3), 6.42 (1H, d, J =16.0 Hz, CH-2'), 7.26–7.65 (4H, m, ArH), 8.08(1H, d, J =16.0 Hz, CH-3'); ¹³C NMR(CDCl₃, 100 MHz) δ : 166.2 (C-1'), 140.0 (C-3'), 134.8 (Ar-C-2), 132.7 (Ar-C-1), 130.8 (Ar-C-3), 130.0 (Ar-C-4), 127.5 (Ar-C-6), 126.9 (Ar-C-5), 121.3 (C-2'), 81.1 (C-3), 76.6 (C-20), 73.2 (C-25), 70.1 (C-12), 55.9 (C-5), 54.6 (C-17), 51.1 (C-14), 49.7 (C-9), 48.9 (C-13), 39.7 (C-8), 38.5 (C-1), 38.0 (C-4), 37.0 (C-24), 36.3 (C-10), 35.6 (C-22), 34.7 (C-7), 32.9 (C-27), 31.0 (C-15), 30.4 (C-11), 28.0 (C-26), 27.0 (C-29), 25.1 (C-2), 23.7 (C-16), 19.3 (C-21), 18.1 (C-6), 16.9 (C-30), 16.5 (C-23), 16.2 (C-18), 16.1 (C-19), 15.5 (C-28).

化合物 9 白色粉末, 收率 63.5%; ESI-MS(m/z): 609.9[M+H]⁺; ¹H NMR(500 MHz, CDCl₃) δ : 0.89, 0.89, 0.93, 0.93, 0.99, 1.20, 1.24, 1.25, 1.28 (24H, s, 8 $\times$ CH₃), 3.57–3.62 (1H, m, CH-12), 4.60–4.64(1H, m, CH-3), 6.36(1H, d, J =16.0 Hz, CH-2'), 7.61(1H, d, J =16.0 Hz, CH-3'), 7.02–7.53 (4H, m, ArH); ¹³C NMR(CDCl₃, 125 MHz) δ : 166.6 (C-1'), 162.8 (Ar-C-4), 142.9 (C-3'), 130.8 (Ar-C-1), 129.8 (Ar-C-2), 129.8 (Ar-C-6), 118.6 (C-2'), 116.0 (Ar-C-3), 115.8 (Ar-C-5), 80.9 (C-3), 76.6 (C-20), 73.5 (C-25), 70.4 (C-12), 56.0 (C-5), 54.6 (C-17), 51.2 (C-14), 49.8 (C-9), 48.9 (C-13), 39.8 (C-8), 38.6 (C-1), 38.1 (C-4), 37.0 (C-24), 36.4 (C-10), 35.7 (C-22), 34.8 (C-7), 32.9 (C-27), 31.1 (C-15), 30.2 (C-11), 28.0 (C-26), 27.1 (C-29), 25.1 (C-2), 23.8 (C-16), 19.3 (C-21), 18.2 (C-6), 16.9 (C-30), 16.6 (C-23), 16.2 (C-18), 16.2 (C-19), 15.6 (C-28).

化合物 10 淡黄色粉末, 收率 44.0%; ESI-MS(m/z): 636.9 [M+H]⁺; ¹H NMR (500 MHz, CDCl₃) δ : 0.87 (3H, s, H-19), 0.89 (3H, s, H-30), 0.93 (3H, s, H-28), 0.93 (3H, s, H-18), 0.99 (3H, s, H-29), 1.19

(3H,s,H-26),1.25 (3H,s,H-27),1.27 (3H,s,H-21),3.55-3.60 (1H,m,CH-12),7.26-7.67 (4H,m,ArH),4.61-4.64 (1H,m,CH-3),6.37 (1H,d, $J=15.7$ Hz,C-2'),8.11 (1H,d, $J=15.7$ Hz,C-3');¹³C NMR (CDCl₃,125 MHz) δ :165.5 (C-1'),139.4 (Ar-C-2),133.4(C-3'),130.7(Ar-C-5),130.1(Ar-C-4),129.0 (Ar-C-1),129.0 (Ar-C-6),124.9 (Ar-C-3),123.9 (C-2'),81.5 (C-3),76.7 (C-20),73.3 (C-25),70.1 (C-12),55.9 (C-5),54.6 (C-17),51.2 (C-14),49.8 (C-9),49.0(C-13),39.8(C-8),38.5(C-1),38.1(C-4),37.0 (C-24),36.4 (C-10),35.7 (C-22),34.8 (C-7),32.9 (C-27),31.1 (C-15),30.4 (C-11),28.0 (C-26),27.1 (C-29),25.1 (C-2),23.7 (C-16),19.3 (C-21),18.2 (C-6),17.0 (C-30),16.5 (C-23),16.2 (C-18),16.1(C-19),15.6(C-28).

2.4 舒张 SD 大鼠血管活性的评价^[20]

2.4.1 血管环的制备 在室温 (22±2)℃条件下,SD 大鼠用 10%水合氯醛(0.35 mL/100 g)腹腔注射麻醉处死后,并迅速取出心脏和大脑于 4℃ MOPS-PSS 液中。体式解剖显微镜下,用显微手术器械将脑基底动脉(BA)周围组织分离干净,将冠状动脉和脑基底动脉剪成约 1 mm 动脉环,穿金属丝备用。

2.4.2 血管环的平衡 体式解剖显微镜下,用两根 60 μ m 的金属丝穿过血管环,分别挂置于 DMT 浴槽中的方向相反的一对金属固定器上。浴槽中盛 MOPS-PSS 工作液 5 mL,恒温 37℃并且持续通入 95%O₂ 和 5%CO₂ 的混合气体。每隔 20 min 换 1 次 MOPS-PSS 工作液,平衡 60 min。然后更换 MOPS-KPSS 工作液(含 60 mM K⁺)5 min,检测血管环活性。当收缩力为预负荷 2 倍左右时认为活性合格,可用于实验。然后按照预先计算的给药体积加药。

2.4.3 受试药物舒张 SD 大鼠血管活性检测 BA 平衡并检测血管环活性合格后,加入 60 mM KCl 收缩血管,待收缩达到最大值且平衡后,将事先 DMSO 配制成浓度为 100 mM 的受试样品 15 μ L 加入到 5 mL 的营养液中就成为最终浓度(300 μ M)。用 PowerLAB 数据记录和分析系统采集数据。每一个受试药物取 8 根血管环进行重复试验。

2.4.4 数据处理 本实验数据结果采用相对张力值(%)来表示,相对张力值小于 50%时,认为有较为显著的血管舒张活性,相对张力值越小表示药物对血管的舒张活性可能越好。相对张力值计算公式为:相对张力值=(X-平衡值)/(60 mM K⁺收缩值-平衡值)×100%(X 表示给药后 PowerLAB 采集到的有效数值)。阳性对照为人参皂苷 Rg1。

表 1 化合物舒张脑基底动脉 BA 血管活性结果

Compounds	浓度(μ M)	相对张力值(% of 60 mM K ⁺)
1	300	40.64
3	300	34.05
4	300	41.38
7	300	34.84
Rg1	300	61.91

由表 1 实验结果可以看出,化合物 **1,3,4,7** 有显著的舒张 BA 血管活性,其活性高于阳性对照人参皂苷 Rg1。

3 讨论

本研究通过人参二醇经酰化反应得到 10 个酰化产物,利用 SD 大鼠脑基底动脉建立的离体模型,将 10 个衍生物进行了舒张 SD 大鼠脑基底动脉活性的初步筛选研究,发现化合物 **1,3,4,7** 的相对张力值均小于 50%,差异有统计学意义,初步表明化合物 **1,3,4,7** 对 SD 大鼠脑基底动脉具有一定的舒张活性,根据相对张力值的计算公式结合药理实验的设计方案,初步推测认为相对张力值越小,舒张血管活性可能越好,但需进一步的体内药理活性研究。这些实验结果为人参二醇的结构改造和构效关系的探讨提供了一定依据,为进一步寻找更加理想舒张血管活性的人参二醇衍生物提供了思路。

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