Marine Diterpenoids with a Briarane Skeleton from the Okinawan Soft Coral *Pachyclavularia violacea*

Hisanaka Ito,*[,a] Junya Iwasaki,[a] Yuki Sato,[a] Miwako Aoyagi,[a] Kazuo Iguchi,*[,a] and Takao Yamori[b]

[a] *School of Life Sciences, Tokyo University of Pharmacy and Life Sciences; Horinouchi, Hachioji, Tokyo 192–0392, Japan: and* [b] *Cancer Chemotherapy Center, Japanese Foundation for Cancer Research; Ariake, Koto-ku, Tokyo 135–8550, Japan.*
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Five new briarane-type diterpenoids, pachyclavulides E (5), F (6), G (7), H (8) and I (9), were isolated from the Okinawan soft coral *Pachyclavularia violacea*. The structures of these compounds were elucidated based on the results of spectroscopic analysis. Compound 5 showed a weak growth-inhibitory activity *in vitro* toward cancer cells.

Key words soft coral; *Pachyclavularia violacea*; marine diterpenoid; briarane skeleton

Marine diterpenoids having a briarane skeleton have been afforded attention owing to their structural features and biological activities.[1—3] The structures of these diterpenoids are characterized by a highly oxygenated bicyclo[8.4.0]tetradecane skeleton frequently with a γ-lactonic moiety. These diterpenoids exhibited a variety of biological activities such as antiinflammatory,[4] cytotoxicity,[5] and reversal of multidrug resistance.[6,7] More than 300 briarane-type diterpenoids have been reported so far mainly from gorgonian octocorals of the genera *Briareum*, *Ellisella* and *Junceella*, and from sea pens of the genera *Stylatula*, *Pteroides* and *Pterosarcus*. Conversely, examples of this type of diterpenoids from alcyonarian and stoloniferan soft corals are limited. Only two reports[8,9] were published on the briarane-type diterpenoids from the stoloniferan soft coral of the genus *Pachyclavularia*. Previously we reported the structures of four new briarane-type diterpenoids, pachyclavulides A (**1**), B (**2**), C (**3**) and D (**4**),[10] from the Okinawan soft coral *Pachyclavularia violacea*. Further investigation on diterpenoids of the soft coral resulted in the isolation of five new diterpenoids, pachyclavulides E (**5**), F (**6**), G (**7**), H (**8**) and I (**9**). This paper describes the structures of these diterpenoids together with their biological activity.

The molecular formula of pachyclavulide E (**5**) containing a chlorine atom was found to be $C_{24}H_{29}ClO_{10}$ by the high-resolution electrospray mass spectrum (HR-ESI-MS) and ^{13}C-NMR data. The IR spectrum showed absorptions at 3467 cm^{-1} due to hydroxyl groups and at 1782, 1747, 1729 and 1698 cm^{-1} due to carbonyl groups. The ^{13}C-NMR spectrum (Table 1) disclosed the signals due to five methyls, one sp^3 methylene, six sp^3 methines, four sp^3 quaternary carbons, four sp^2 methines, and four carbonyl carbons. One of the carbonyl carbons (δ_C 201.1) was assignable to the ketonic carbon of a conjugated enone. The UV spectrum showed absorption at 225 (ε 3050) nm, indicating also the presence of the conjugated enone. The presence of a γ-lactone was indicated by the IR absorption at 1782 cm^{-1} and the ^{13}C signal of 175.7 (C) ppm. The ^{1}H-NMR spectrum (Table 1) showed the signals due to one secondary methyl, two tertiary methyls, two acetoxyl methyls, one epoxydic sp^3 methylene, two sp^3 methines, three sp^3 oxymethines, one sp^3 methine bearing a chlorine atom, four olefinic protons, and two hydroxyl protons. These spectral data, coupled with ten degrees of unsaturation, suggested that compound **5** is a tetracyclic diterpenoid with a γ-lactone, a conjugated enone, an epoxide and two acetoxyl groups.

The HMQC analysis revealed the assignment of each direct C–H bonding in **5** as summarized in Table 1. The ^{1}H–^{1}H correlations obtained from ^{1}H–^{1}H COSY are shown by the bold lines in Fig. 2 to give five partial structures, which were connected by the HMBC correlations as shown by the broken arrows in Fig. 2. The HMBC correlations from H-2 to C-1, from H-10 to C-1, from H-14 to C-1 and C-15, and from H-15 to C-1 and C-14 indicated the structural unit around the quaternary carbon at C-1. The structural unit around the

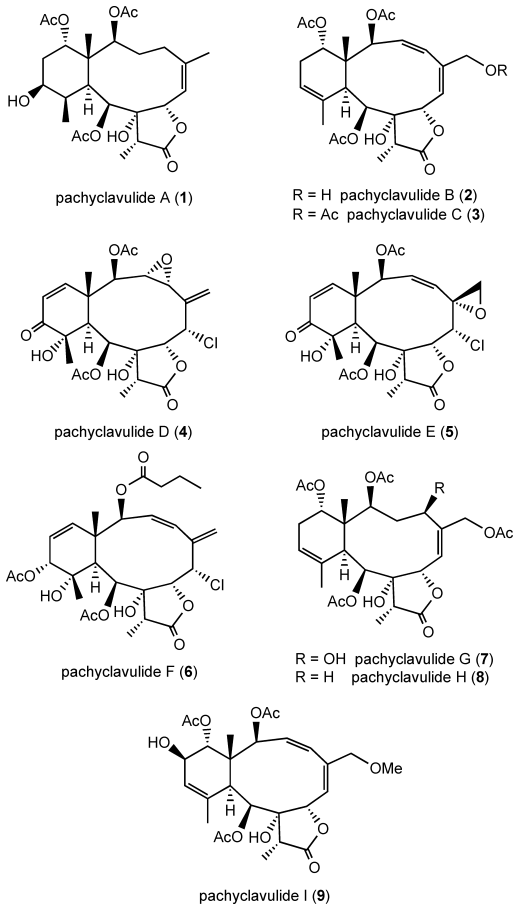

Fig. 1. Structures of Pachyclavulides A (**1**)—D (**4**) Reported Previously and Pachyclavulides E (**5**)—I (**9**) Isolated in the Present Study

* To whom correspondence should be addressed. e-mail: itohisa@ls.toyaku.ac.jp; onocerin@ls.toyaku.ac.jp

Table 1. NMR Data[a] for **5** and **6**

Position	**5**		Position	**6**	
	δ_C	δ_H		δ_C	δ_H
1	45.8 (C)		1	45.9 (C)	
2	77.7 (CH)	6.14 (1H, d, 8.2)	2	77.3 (CH)	5.98 (1H, d, 9.1)
3	129.3 (CH)	5.44 (1H, dd, 8.2, 11.7)	3	129.2 (CH)	5.55 (1H, dd, 9.1, 11.8)
		2.83 (1H, dd, 12.6, 15.2)			2.63 (1H, m)
4	131.8 (CH)	5.70 (1H, dd, 11.7)	4	128.9 (CH)	5.915 (1H, d, 11.8)
5	89.4 (C)		5	137.1 (C)	
6	64.1 (CH)	4.43 (1H, d, 5.5)	6	61.9 (CH)	5.10 (1H, br m)
7	81.3 (CH)	4.59 (1H, d, 5.5)	7	78.9 (CH)	5.05 (1H, d, 4.1)
8	91.7 (C)		8	83.0 (C)	
9	74.5 (CH)	6.07 (1H, br s)	9	69.1 (CH)	5.74 (1H, d, 6.2)
10	50.2 (CH)	2.76 (1H, br s)	10	39.2 (CH)	3.17 (1H, d, 6.2)
11	74.1 (C)		11	75.4 (C)	
12	201.1 (C)		12	72.8 (CH)	4.93 (1H, d, 3.0)
13	122.4 (CH)	6.06 (1H, d, 10.8)	13	121.4 (CH)	5.74 (1H, m)
14	155.7 (CH)	7.03 (1H, d, 10.8)	14	142.5 (CH)	5.74 (1H, m)
15	16.4 (CH_3)	1.41 (3H, s)	15	14.8 (CH_3)	1.10 (3H, s)
16	66.2 (CH_2)	3.79 (2H, m)	16	116.8 (CH_2)	5.920 (1H, br s)
17	45.2 (CH)	3.09 (1H, q, 7.1)			6.19 (1H, br s)
18	10.4 (CH_3)	1.31 (3H, d, 7,1)	17	45.5 (CH)	2.37 (1H, q, 7.1)
19	175.7 (C)		18	6.9 (CH_3)	1.21 (3H, d, 7.1)
20	24.2 (CH_3)	1.29 (3H, s)	19	175.0 (C)	
Ac[b]	169.5 (C)		20	23.5 (CH_3)	1.38 (3H, s)
	21.2 (CH_3)	2.12 (3H, s)	Ac[d]	170.1 (C)	
Ac[c]	168.9 (C)			22.0 (CH_3)	2.17 (3H, s)
	21.5 (CH_3)	2.18 (3H, s)	Ac[e]	172.0 (C)	
OH		2.49 (1H, br s)		20.9 (CH_3)	2.08 (3H, s)
OH		3.84 (1H, s)	Bu1[f]	172.4 (C)	
			Bu2[f]	36.3 (CH_2)	2.33 (2H, t, 7.4)
			Bu3[f]	18.4 (CH_2)	1.68 (2H, m)
			Bu4[f]	13.7 (CH_3)	0.97 (3H, t, 7.4)
			OH		5.22 (1H, br s)

a) ^{13}C-NMR: 125 MHz in $CDCl_3$, ^{1}H-NMR: 500 MHz in $CDCl_3$. *J* in Hz. Assignments of ^{13}C and ^{1}H signals were made based on HMQC. *b*—*e*) The positions of these acetoxyl groups are at C-2 for *b*), C-9 for *c*) and *d*), and C-12 for *e*). *f*) Bu1—Bu4 are the numbers of the butoxyl group at C-2.

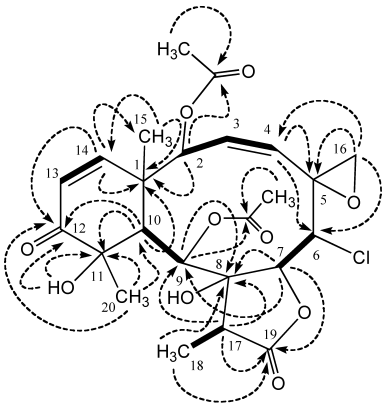

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Fig. 2. Gross Structure, ^{1}H–^{1}H Correlations (Bold Lines) and Key HMBC Correlations (Broken Arrows) of Pachyclavulide E (**5**)

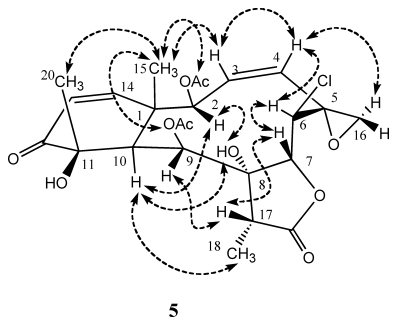

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Fig. 3. Key NOE Correlations (Broken Arrows) and Possible Conformation of Pachyclavulide E (**5**)

epoxide moiety was demonstrated by the HMBC correlations from H-4 to C-5 and C-6, and from H-16 to C-4, C-5 and C-6. The presence of a β-hydroxy-α-methylbutanolide moiety on the cyclodecane ring was exhibited by the HMBC correlations from H-7 to C-8, C-9 and C-19, from H-9 to C-8, from H-17 to C-8, C-9 and C-19, and from H-18 to C-8 and C-19. Finally, the presence of an α-hydroxy-α-methylketone moiety was indicated by the HMBC correlations from H-10 to C-11 and C-12, from H-14 to C-12, from H-20 to C-10, C-11 and C-12, and from the hydroxylic proton to C-11 and C-12. These findings led to the gross structure for **5**.

The *Z* configuration of the disubstituted double bond at C-3 was determined by the coupling constant (J=11.7 Hz) between H-3 and H-4. The relative stereochemistry of the ten chiral centers in **5** was deduced from the analysis of NOE correlations as shown by the broken lines in Fig. 3 with supporting information from vicinal coupling constants (Table 1). The NOE correlations between H-15 (CH_3) and H-20 (CH_3), H-15 and OAc at C-2, H-15 and OAc at C-9, H-15 and H-3, H-3 and H-4, H-4 and H-6, and H-4 and H-16 indicated that these protons orient to the same side giving the relative configurations at C-1, C-2, C-5, C-6, C-9 and C-11.

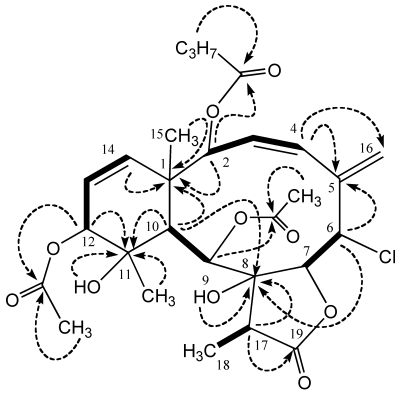

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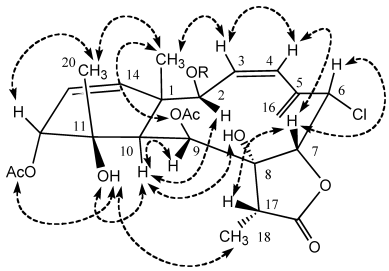
Fig. 4. Gross Structure, ^{1}H–^{1}H Correlations (Bold Lines) and Key HMBC Correlations (Broken Arrows) of Pachyclavulide F (**6**)



6 R = COC_3H_7

Fig. 5. Key NOE Correlations (Broken Arrows) and Possible Conformation of Pachyclavulide F (**6**)

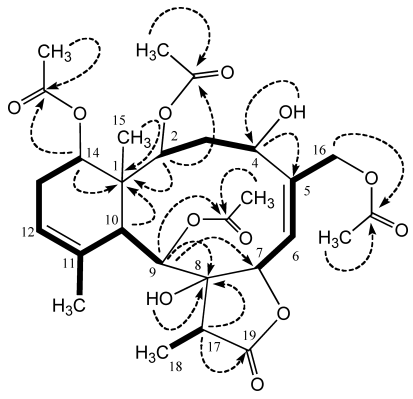


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Fig. 6. Gross Structure, ^{1}H–^{1}H Correlations (Bold Lines) and Key HMBC Correlations (Broken Arrows) of Pachyclavulide G (**7**)

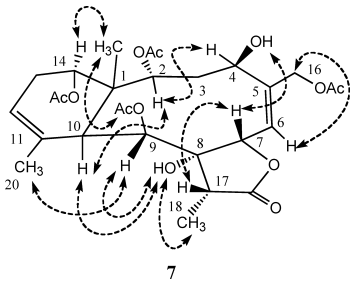

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Fig. 7. Key NOE Correlations (Broken Arrows) and Possible Conformation of Pachyclavulide G (**7**)

Conversely, NOEs between H-2 and H-10, H-10 and H-18 (CH_3), and H-10 and the hydroxyl proton at C-8 indicated these protons reside on the opposite side giving the relative configurations at C-8, C-10 and C-17. The small coupling constant between H-9 (br s) and H-10 (br s) demonstrated a dihedral angle of almost 90°, and supported the conformation between C-9 and C-10. The remaining relative configuration at C-7 was determined by the NOEs between H-7 and H-17, and H-17 and H-9. The absolute stereochemistry of **5** must be the same as that of pachyclavulide A (**1**)[10] present in the same soft coral.

The molecular formula of pachyclavulide F (**6**) containing a chlorine atom was found to be $C_{28}H_{37}ClO_{10}$ by the HR-ESI-MS and ^{13}C-NMR data. The NMR data of **6** (Table 1) were similar to those of **5**, except for the signals due to an exomethylene, a butoxyl group and an additional oxymethine instead of the ketone group of the conjugated enone, the epoxydic methylene, and one of the acetoxyl groups in **5**. These findings, coupled with ten degrees of unsaturation, suggested that compound **6** is a briarane-type tricyclic diterpenoid with a γ-lactone, an exomethylene, a butoxyl group and two acetoxyl groups. The gross structure for **6** was obtained from the analyses of HMQC, ^{1}H–^{1}H COSY (bold lines in Fig. 4) and HMBC (broken lines in Fig. 4). The *Z* configuration of the disubstituted double bond at C-3 was determined by the coupling constant (J=11.8 Hz) between H-3 and H-4. The relative stereochemistry of the ten chiral centers in **6** was deduced from the analysis of NOE correlations as shown by the broken arrows in Fig. 5 with supporting information from vicinal coupling constants (Table 1). The absolute stereochemistry of **6** must be the same as that of pachyclavulide A (**1**)[10] present in the same soft coral.

The following diterpenoids, pachyclavulides G, H and I, do not contain any halogen atom. The spectral data of pachyclavulide G (**7**) ($C_{28}H_{38}O_{12}$), coupled with ten degrees of unsaturation, suggested that compound **7** is a briarane-type tricyclic diterpenoid with a γ-lactone and four acetoxyl groups. The HMQC analysis revealed the assignment of each direct C–H bonding in **7** as summarized in Table 2. The ^{1}H–^{1}H correlations obtained from ^{1}H–^{1}H COSY are shown by the bold lines in Fig. 6 to give four partial structures, which were connected by the HMBC correlations, indicated by the broken arrows in Fig. 6, leading to the gross structure for **7**. The *E* configuration of the trisubstituted double bond at C-5 was determined by the NOE correlation between H-6 and H-16 (Fig. 7). The relative stereochemistry of the nine chiral centers in **7** was deduced from the analysis of NOE correlations as shown by the broken arrows in Fig. 7 with supporting information from vicinal coupling constants (Table 2). The absolute stereochemistry of **7** as well as pachyclavulides H and I must be the same as that of pachyclavulide A (**1**)[10] present in the same soft coral.

The molecular formula of pachyclavulide H (**8**) was found to be $C_{28}H_{38}O_{11}$, which loses one oxygen atom from the molecular formula of **7** ($C_{28}H_{38}O_{12}$), by the HR-ESI-MS and ^{13}C-NMR data. The ^{13}C- and ^{1}H-NMR spectra (Table 2) of **8** were very similar to those of **7**, except for the signals due to an additional methylene group instead of the secondary hydroxyl group at C-4 in **7**. The structure of **8** involving the relative stereochemistry was determined by the analysis of HMQC, ^{1}H–^{1}H COSY (Fig. 8), HMBC (Fig. 8) and NOESY

Table 2. NMR Data[a] for **7** and **8**

Position	**7**		Position	**8**	
	δ_C	δ_H		δ_C	δ_H
1	44.6 (C)		1	44.4 (C)	
2	73.9 (CH)	4.80 (1H, d, 7.9)	2	74.7 (CH)	4.96 (1H, d, 9.3)
3	40.3 (CH_2)	2.08 (1H, m)	3	31.7 (CH_2)	1.70 (1H, m)
		2.83 (1H, dd, 12.6, 15.2)			2.63 (1H, m)
4	66.8 (CH)	4.21 (1H, dd, 5.3, 12.6)	4	25.1 (CH_2)	1.89 (1H, dt, 3.0, 15.0)
5	144.0 (C)				2.50 (1H, m)
6	123.6 (CH)	5.77 (1H, d, 10.0)	5	143.7 (C)	
7	79.2 (CH)	6.02 (1H, d, 10.0)	6	117.3 (CH)	5.48 (1H, d, 9.8)
8	81.8 (C)		7	78.0 (CH)	5.40 (1H, d, 9.8)
9	69.5 (CH)	6.04 (1H, d, 2.4)	8	81.9 (C)	
10	39.7 (CH)	3.04 (1H, br s)	9	69.9 (CH)	6.03 (1H, br s)
11	135.2 (C)		10	40.1 (CH)	2.82 (1H, br s)
12	119.9 (CH)	5.41 (1H, br d, 4.2)	11	134.3 (C)	
13	26.4 (CH_2)	1.98 (1H, m)	12	120.7 (CH)	5.43 (1H, br d, 3.2)
		2.21 (1H, m)	13	26.6 (CH_2)	1.98 (1H, m)
14	73.3 (CH)	4.78 (1H, br s)			2.23 (1H, br d, 19.0)
15	14.3 (CH_3)	0.98 (3H, s)	14	73.2 (CH)	4.78 (1H, br s)
16	67.0 (CH_2)	4.91 (1H, d, 14.2)	15	14.2 (CH_3)	0.93 (3H, br s)
		4.99 (1H, d, 14.2)	16	67.4 (CH_2)	4.54 (1H, d, 15.4)
17	43.8 (CH)	2.48 (1H, q, 7.1)			4.98 (1H, d, 15.4)
18	6.7 (CH_3)	1.23 (3H, d, 7.1)	17	43.1 (CH)	2.51 (1H, q, 7.1)
19	178.9 (C)		18	7.0 (CH_3)	1.25 (3H, d, 7.1)
20	24.4 (CH_3)	2.02 (3H, br s)	19	176.0 (C)	
Ac[b]	170.9 (C)		20	24.3 (CH_3)	1.98 (3H, s)
	21.2 (CH_3)	2.03 (3H, s)	Ac[f]	170.7 (C)	
Ac[c]	169.9 (C)			21.1 (CH_3)	2.02 (3H, s)
	21.6 (CH_3)	2.20 (3H, s)	Ac[g]	169.6 (C)	
Ac[d]	171.2 (C)			21.5 (CH_3)	2.18 (3H, s)
	21.3 (CH_3)	1.93 (3H, s)	Ac[h]	171.3 (C)	
Ac[e]	172.2 (C)			21.3 (CH_3)	1.96 (3H, s)
	21.3 (CH_3)	2.13 (3H, s)	Ac[i]	170.4 (C)	
OH		4.45 (1H, br s)		20.9 (CH_3)	2.13 (3H, s)
OH		4.58 (1H, br s)			

a) ^{13}C-NMR: 125 MHz in $CDCl_3$, ^{1}H-NMR: 500 MHz in $CDCl_3$. *J* in Hz. Assignments of ^{13}C and ^{1}H signals were made based on HMQC. *b*—*i*) The positions of these acetoxyl groups are at C-2 for *b*) and *f*), C-9 for *c*) and *g*), at C-14 for *d*) and *h*), and C-16 for *e*) and *i*).

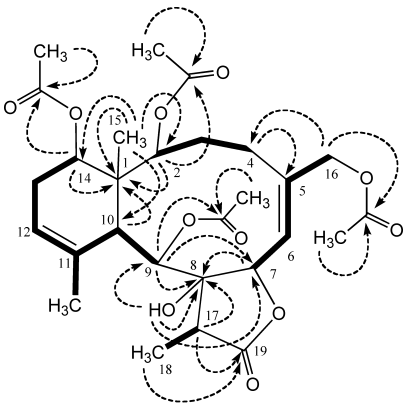

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Fig. 8. Gross Structure, ^{1}H–^{1}H Correlations (Bold Lines) and Key HMBC Correlations (Broken Arrows) of Pachyclavulide H (**8**)

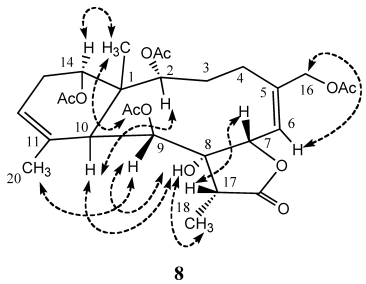

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Fig. 9. Key NOE Correlations (Broken Arrows) and Possible Conformation of Pachyclavulide H (**8**)

(Fig. 9).

The spectral data of pachyclavulide I (**9**) ($C_{27}H_{36}O_{11}$), coupled with ten degrees of unsaturation, suggested that compound **9** is a briarane-type tricyclic diterpenoid with a γ-lactone, three acetoxyl groups and a methoxymethyl group. The gross structure of **9** was obtained from the analyses of HMQC, ^{1}H–^{1}H COSY (bold lines in Fig. 10) and HMBC (broken lines in Fig. 10). The *Z* configuration of the disubstituted double bond at C-3 was determined by the coupling constant (J=11.0 Hz) between H-3 and H-4. Conversely, the *E* configuration of the trisubstituted double bond at C-5 was indicated by the NOE correlation between H-6 and H-16 (Fig. 11). The relative stereochemistry of the nine chiral centers in **9** was deduced from the analysis of NOE correlations as shown by the broken arrows in Fig. 11 with supporting information from vicinal coupling constants (Table 3).

The cytotoxic activity for pachyclavulides A (**1**), B (**2**), C (**3**), E (**5**) and F (**6**) against cultured cancer cells was evaluated in the Jpn. Fdn. For Cancer Research 39 cell line

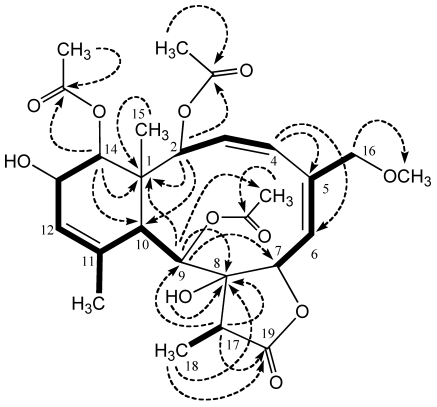

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Fig. 10. Gross Structure, ^{1}H–^{1}H Correlations (Bold Lines) and Key HMBC Correlations (Broken Arrows) of Pachyclavulide I (**9**)

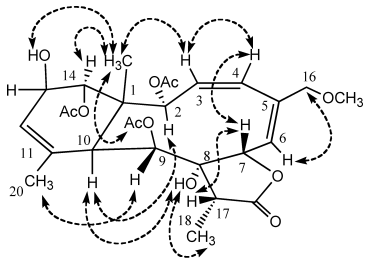

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Fig. 11. Key NOE Correlations (Broken Arrows) and Possible Conformation of Pachyclavulide I (**9**)

assay.[11] Pachyclavulide B (**2**) showed weak cytotoxic activity (GI_{50} 5.2 μM) against the CNS cancer cell line (SNB-75) and pachyclavulide E (**5**) also showed weak cytotoxic activity (GI_{50} 5.1 μM) against the lung cancer cell line (A549). The other pachyclavulides did not show any significant activity.

Experimental

General Procedures Optical rotations were measured with a JASCO DIP-370 automatic polarimeter. IR spectra were recorded with a Perkin-Elmer FT-IR 1600 spectrophotometer. All NMR spectra were recorded with a Bruker DRX-500 (^{1}H; 500 MHz, ^{13}C; 125 MHz) spectrometer. ^{1}H–^{1}H COSY, NOESY, HMQC and HMBC spectra were measured using standard Bruker pulse sequences. Chemical shifts are given on a δ (ppm) scale with $CHCl_3$ (^{1}H; 7.26 ppm) and $CDCl_3$ (^{13}C; 77.0 ppm) as the internal standard. Mass spectra were taken with a Micromass LCT spectrometer.

Extraction and Isolation The soft coral *Pachyclavularia violacea* (order Stolonifera, class Clavularidae)[12] was collected from a coral reef off Ishigaki Island, Okinawa Prefecture, Japan, in September 1995. A voucher specimen has been deposited at Tokyo University of Pharmacy and Life Sciences, Tokyo, Japan.

Wet specimens (2.3 kg) of the soft coral collected in 1995 were extracted with MeOH. The MeOH extract (103 g) was partitioned between EtOAc and H_2O to obtain an EtOAc soluble portion (41.0 g). A part (5.16 g) of the EtOAc soluble portion was chromatographed on a silica gel column. Elution with hexane–EtOAc (1 : 1) afforded five fractions A—E. The third fraction C (1.26 g) was subjected to silica gel column chromatography [hexane–EtOAc (3 : 2)] to afford four fractions. A part (198 mg) of the second fraction (372 mg) was further subjected to repeated HPLC separation (normal and reverse) to afford pachyclavulides F (**6**) (11 mg) and H (**4**) (12 mg). Silica gel column chromatography of the fourth fraction D (1.98 g) afforded five fractions. From the fourth fraction (277 mg), pachyclavulides E (**5**) (11 mg), G (**7**) (5 mg) and I (**9**) (3 mg) were afforded by repeated purification using HPLC (normal and reverse).

Pachyclavulide E (**5**): Colorless amorphous solids; $[\alpha]_D^{25}$ +46.8° (c=0.77, $CHCl_3$); UV (EtOH) λ_{max} 225 (ε 3050) nm; IR (film) ν_{max} 3467, 1782, 1747, 1729, 1698, 1217 cm^{-1}; ^{13}C- and ^{1}H-NMR, see Table 1; HR-ESI-MS m/z 535.1326 $[M+Na]^+$ (Calcd for $C_{24}H_{29}{}^{35}ClO_{10}Na$, 535.1347).

Pachyclavulide F (**6**): Colorless amorphous solids; $[\alpha]_D^{25}$ −208.6° (c=0.77, $CHCl_3$); IR (film) ν_{max} 3292, 1778, 1738, 1731, 1715, 1223 cm^{-1}; ^{13}C- and ^{1}H-NMR, see Table 1; HR-ESI-MS m/z 569.2154 $[M+H]^+$ (Calcd for $C_{28}H_{38}{}^{35}ClO_{10}$, 569.2161).

Pachyclavulide G (**7**): Colorless amorphous solids; $[\alpha]_D^{25}$ +9.7° (c=0.44, $CHCl_3$); IR (film) ν_{max} 3396, 1732, 1252, 1219 cm^{-1}; ^{13}C- and ^{1}H-NMR, see Table 2; HR-ESI-MS m/z 567.2439 $[M+H]^+$ (Calcd for $C_{28}H_{39}O_{12}$, 567.2442).

Pachyclavulide H (**8**): Colorless amorphous solids; $[\alpha]_D^{25}$ +28.7° (c=0.78, $CHCl_3$); IR (film) ν_{max} 3443, 1769, 1747. 1731, 1714, 1694, 1682, 1219 cm^{-1}; ^{13}C- and ^{1}H-NMR, see Table 2; HR-ESI-MS m/z 551.2480 $[M+H]^+$ (Calcd for $C_{28}H_{39}O_{11}$, 551.2492).

Pachyclavulide I (**9**): Colorless amorphous solids; $[\alpha]_D^{25}$ −38.9° (c=0.17, $CHCl_3$); IR (film) ν_{max} 3434, 1769, 1741, 1738, 1732, 1716, 1698 1223 cm^{-1}; ^{13}C- and ^{1}H-NMR, see Table 3; HR-ESI-MS m/z 537.2347 $[M+H]^+$ (Calcd for $C_{27}H_{37}O_{11}$, 537.2336).

Table 3. NMR Data[a] for **9**

Position	**9**	
	δ_C	δ_H
1	43.0 (C)	
2	75.2 (CH)	5.37 (1H, d, 9.6)
3	132.2 (CH)	5.73 (1H, dd, 9.6, 11.0)
4	127.4 (CH)	6.23 (1H, d, 11.0)
5	144.5 (C)	
6	120.0 (CH)	5.75 (1H, d, 8.9)
7	79.8 (CH)	5.22 (1H, d, 8.9)
8	81.2 (C)	
9	68.6 (CH)	5.94 (1H, d, 4.5)
10	39.6 (CH)	3.06 (1H, br s)
11	138.4 (C)	
12	123.2 (CH)	5.68 (1H, br m)
13	66.2 (CH)	3.86 (1H, br s)
14	76.3 (CH)	4.93 (1H, br s)
15	14.5 (CH_3)	1.18 (3H, s)
16	72.3 (CH_2)	4.01 (1H, d, 15.6)
		4.45 (1H, d, 15.6)
17	44.4 (CH)	2.45 (1H, q, 7.1)
18	7.3 (CH_3)	1.28 (3H, d, 7.1)
19	175.7 (C)	
20	24.7 (CH_3)	2.04 (3H, br s)
Ac[b]	169.5 (C)	
	21.3 (CH_3)	2.01 (3H, s)
Ac[c]	169.8 (C)	
	21.5 (CH_3)	2.18 (3H, s)
Ac[d]	170.7 (C)	
	21.1 (CH_3)	2.00 (3H, s)
OMe	58.6 (CH_3)	3.43 (3H, s)
OH		2.39 (1H, s)

a) ^{13}C-NMR: 125 MHz in $CDCl_3$, ^{1}H-NMR: 500 MHz in $CDCl_3$. J in Hz. Assignments of ^{13}C and ^{1}H signals were made based on HMQC. *b*—*d*) The positions of these acetoxyl groups are at C-2 for *b*), C-9 for *c*), and at C-14 for *d*).

References and Notes

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