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The Blood Vascular Bed of the Human Pancreas, with Special Reference to the Insulo-Acinar Portal System. Scanning Electron Microscopy of Corrosion Casts*

Takuro MURAKAMI[1], Tsuneo FUJITA[2], Takehito TAGUCHI[1], Yasuyuki NONAKA[1,3] and Kunzo ORITA[3]

Departments of Anatomy[1] and Surgery[3], Okayama University School of Medicine, Okayama; and Department of Anatomy[2], Niigata University School of Medicine, Niigata, Japan

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Summary. **Microdissection and scanning electron microscopy of corrosion casts showed the structures of the vascular bed of the human pancreas to consist mainly of the capillary plexuses of the exocrine lobules, extralobular ducts and endocrine islets.**

A considerable number of the exocrine lobules were found to contain one to four marked endocrine islets larger than 30 μm in diameter. These intralobular islets received one or more arterioles (afferent vessels) and emitted conspicuous insulo-acinar portal vessels which continued into the lobular capillaries, suggesting insular control over the functions of the exocrine acini of the pancreas. Direct drainage of the intralobular islets into the veins was never reproduced. Not excluding the possibility that some lobules might contain smaller, unidentifiable islets, there nonetheless were many lobules which directly received arterioles. These lobules are free of control by an islet.

Rarely, an islet was located in the interlobular tissue space or along an extralobular duct. Such an extralobular islet issued no portal vessels, and drained into the interlobular or periductal veins. The surface of this type of islet comprised a thin network of fine capillaries. A possibility was suggested that this cortical network might be homologous with the lobular capillaries. No portal route was observed between the islets and extralobular ducts. Few connections were noted between the capillary plexuses of the lobules and ducts.

Early light microscopic studies of dye-injected or serially sectioned tissue samples suggested in the horse, rabbit, mouse and in humans that the efferent vessels of the endocrine pancreas (islets of Langerhans) are continuous with the capillaries of the exocrine pancreas (acinar tissue) (BECK and BERG, 1931; WHARTON, 1932; THIEL, 1954). These studies were ignored by other authors who mainly observed the microcirculation of the pancreas in living mice and rats with intravital microscopes (BRUNFELDT et al., 1958; BUNNAG et al., 1963).

However, recent light microscopic studies of India ink-injected tissues and scanning electron microscopic observations of vascular casts have confirmed in the monkey, horse, dog, rabbit and rat that the capillaries of islets issue efferent vessels to the capillary network in the exocrine tissue; this microcirculatory pattern was designated the insulo-acinar portal system (FUJITA, 1973; FUJITA and WATANABE, 1973; FUJITA and MURAKAMI, 1974; FUJITA et al., 1976; OHTANI, 1983; OHTANI et al., 1986).

It has been noted, meanwhile, that in certain animals, especially in the horse, the major portion of the exocrine tissue is supplied by the portal vessels, while in other animals, especially in the rat, large parts of the exocrine tissue are supplied with their proper arterioles. Some authors, furthermore, claimed that in the rat the capillaries in the islets are mainly drained by proper collecting venules (BRUNFELDT et al., 1958; BUNNAG et al., 1963; BONNER-WEIR and ORCI, 1982). It is noteworthy that these claims against the significance of the insulo-acinar portal system have been derived from the observations in the rat, which in fact exhibits quite unique and complicated microcirculation patterns of its pancreas.

As modern techniques have never been previously applied to investigating patterns of pancreatic microcirculation in man, the present study reports results

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obtained from human pancreata. We focus our interest on the extent of development of the insulo-acinar portal system and the possible occurrence of venous drainage of islet capillaries.

MATERIALS AND METHODS

The caudal part of the normal human pancreas, together with the connecting splenic artery and vein, was isolated at autopsy from three Japanese individuals: a 25-year-old woman dying of osteosarcoma, a 45-year-old man dying of gastric cancer, and a 75-year-old man dying of gastric cancer; the latter two men are the same individuals whose kidneys were used for our previous study of the renal glomerulus (MURAKAMI et al., 1985).

The isolated specimens were perfused thoroughly with physiological saline solution first and then with laboratory-prepared and diluted low viscosity methyl methacrylate medium through the splenic artery, warmed in a hot water bath (60°C), corroded in a hot NaOH solution (10%, 60°C), washed with water and neutral detergent, and dried in air (MURAKAMI, 1971, 1975; MURAKAMI et al., 1973).

The blood vascular casts of the human pancreata thus obtained were microdissected with sharpened forceps and needles under a dissecting microscope, in order to expose aspects of interest. The cast pieces were coated with gold, and observed with a scanning electron microscope (S-2300, Hitachi) using an acceleration voltage of 5 kV.

RESULTS

The present observation by scanning electron microscopy proved that infusion of our diluted low viscosity methyl methacrylate medium through the pancreatic branches of the splenic artery could produce satisfactory blood vascular casts of human pancreata (caudal part) obtained at autopsy (Figs. 1-11). In each case, the capillary beds of the endocrine islets, exocrine lobules, secretory ducts and interlobular tissue spaces were sufficiently reproduced together with their connecting arteries and veins (Figs. 1-11). Discontinuities (injection defects) in the casts of capillaries were occasionally noted (Figs. 4, 5, 10). Leakage of the injected resin was only rarely recognized.

Microdissection often caused breakage of vessels of interest. This fault was alleviated by preparing numerous microdissected samples. More than 500 islets were exposed by microdissection and the origins and termiations of the afferent and efferent vessels were checked by scanning electron microscopy (Figs. 6-9).

Little difference could be found among the findings from the three individuals, except for that the capillary plexuses of the exocrine lobules in the aged individuals were coarser than those of the young one (Figs. 4, 5, 10) and that the arteries and veins, including the lobular arteries and veins, of the aged individuals were somewhat more tortuous (Figs. 4, 9, 10).

The interlobular arteries and veins were irregular in their courses, and often did not accompany an interlobular duct (Fig. 1). The interlobular arteries sometimes showed a marked ring-like constriction at their origin from their parent arteries.

Lobular vascular bed

The blood vascular bed of the exocrine lobules (lobular plexus) consisted of fine capillaries, which received one or more afferent vessels (lobular arteries) from the interlobular arteries and issued one or more efferent vessels (lobular veins) continuous to the interlobular veins (Figs. 2, 4). Frequently, an exocrine lobule was closely associated with the interlobular duct (Fig. 3). In such cases, the lobular arteries and veins were derived from the periductal arteries and veins, which arose from the interlobular arteries and veins and supplied the periductal plexus (Fig. 3). The lobular plexus occasionally possessed insignificant fine connections with the interlobular or periductal plexus (Figs. 1, 2). Branching patterns of the lobular arteries and veins in the lobules varied widely among cases. Usualy the terminal branches of the lobular arteries and veins emerged alternately (Fig. 5).

The size of the lobular plexus also varied widely. Large lobules measuring more than 0.5 mm in length contained numerous fine capillaries (lobular capillaries), while small ones 500 μm or less in length contained a small number of lobular capillaries (Figs. 2, 3, 10). Larger lobules were typically located in the superficial layers of the pancreas, whereas smaller ones, in the deeper layers of the organ or in close association with the interlobular ducts (Fig. 1).

The lobular arteries sometimes showed a marked ring-like or V-shaped constriction at their origin. Such a constriction was noted also at the origin of the peripheral branches of the lobular arteries (Fig. 5).

Periductal vascular plexus

The vascular networks surrounding the interlobular and lobular ducts (periductal plexuses) were supplied with periductal arteries and veins which were derived

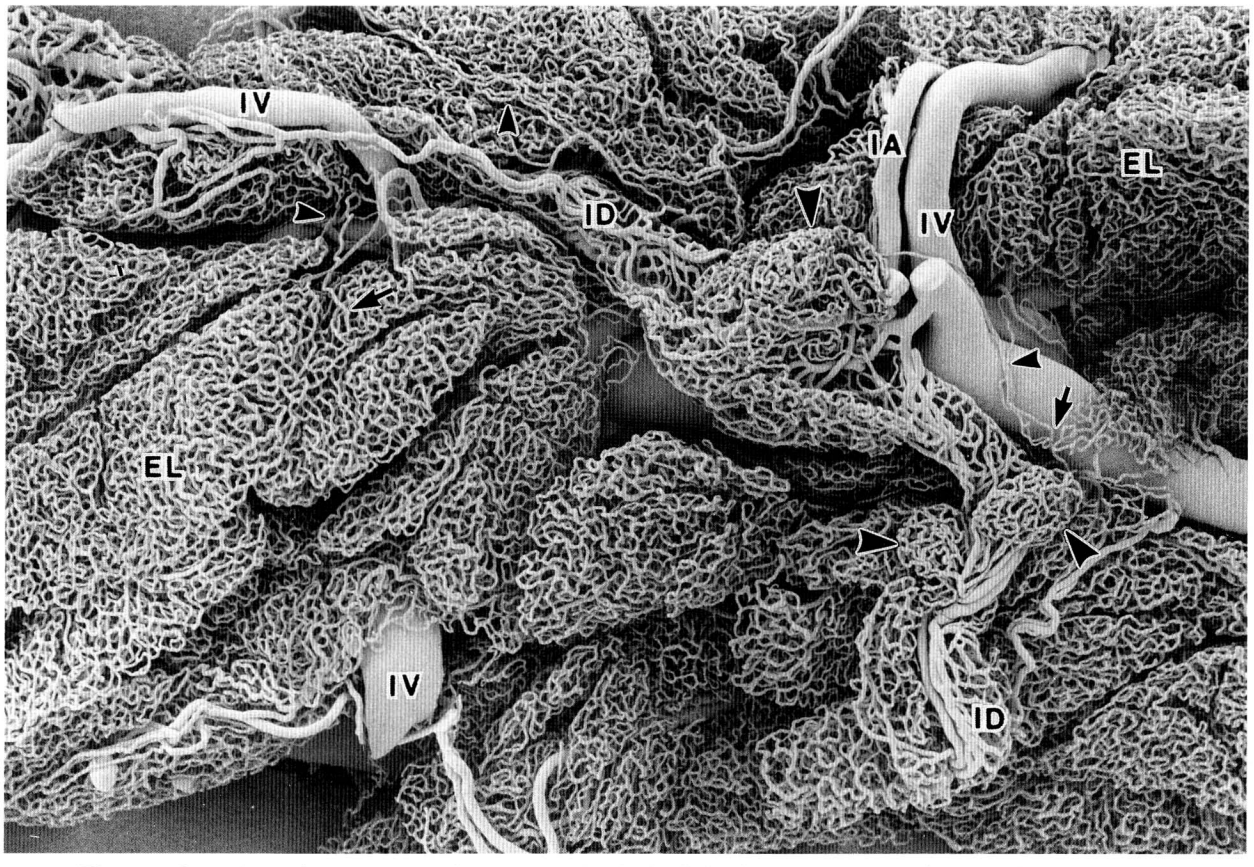


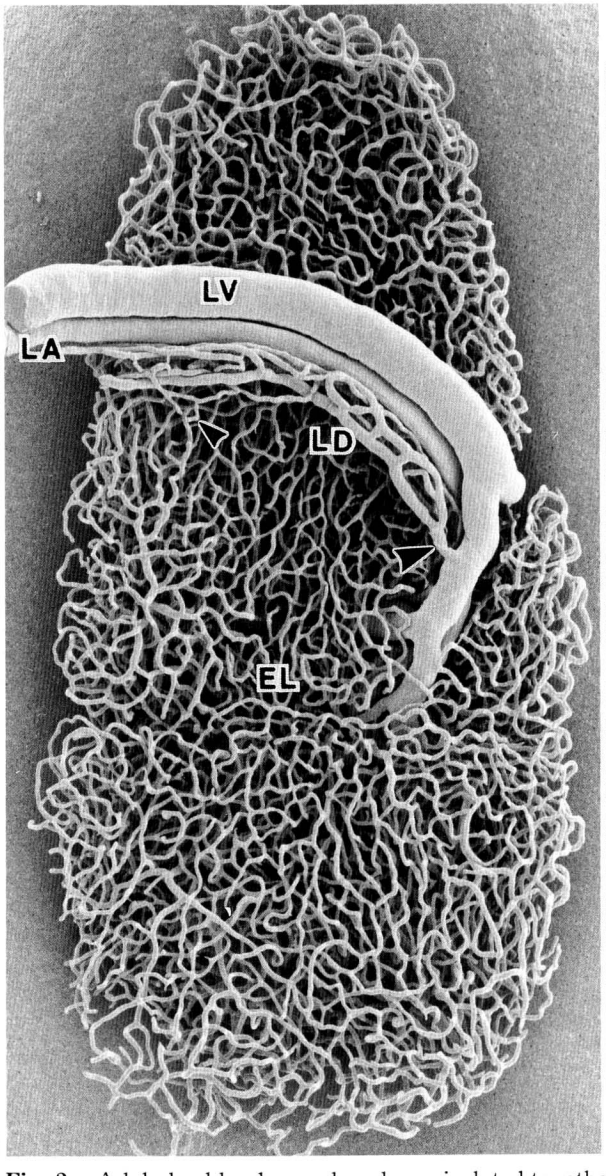
Fig. 1. Overview of a replicated blood vascular bed of the human pancreas (a caudal segment exposed by dissection, 25-year-old woman). Note that the blood vascular plexuses of the exocrine lobules (*EL*) and secretory ducts (interlobular ducts, *ID*) are thoroughly reproduced together with their connecting interlobular arteries (*IA*) and veins (*IV*), and that the exocrine lobules (*large arrowheads*) closely associated with the ducts are smaller than the other lobules. The *small arrowheads* indicate the interlobular blood vascular plexuses, some capillaries of which continue into the lobular capillaries (*arrows*). ×40

Abbreviations used in Figures 1–12.
EI extralobular endocrine islet (islet of Langerhans) or its vascular plexus, *EL* exocrine lobule or its vascular plexus, *IA* interlobular artery, *ID* interlobular duct or its vascular bed, *II* intralobular endocrine islet or its vascular plexus, *IV* interlobular vein, *LA* lobular artery, *LD* lobular duct or its vascular bed, *LV* lobular vein, *PA* periductal artery, *PV* periductal vein, *a* afferent vessel of the islet, *e* efferent vessel of the islet, *s* surface capillary network of the extralobular islet, *v* venous efferent vessel (emissary vein) of the extralobular islet, *la* branch of the lobular artery, *lv* branch of the lobular vein

from the interlobular arteries and veins, respectively (Figs. 1–4). A large- or medium-sized periductal plexus comprised an inner layer of fine capillaries and an outer layer of a venous network. The inner capillary network received periductal arteries and drained into the outer venous network. In a small-sized periductal plexus, such differentiation was not clear, the arteries, capillaries and veins being intermingled in a single layer (Fig. 4). The terminal segments of the periductal plexus (ductal plexus surrounding the lobular ducts) consisted of several capillaries which drained into the lobular veins in or outside the lobular plexus (Fig. 2). Few capillary connections could be recognized between the lobular and ductal plexuses (Figs. 2, 3).

Intralobular islets and their blood vessels

The blood vascular network in the islets of Langerhans (insular plexus) consisted of thicker (sinusoidal) capillaries conglomerated into a globular mass, measuring 30–250 μm (usually, 100–150 μm) in diameter



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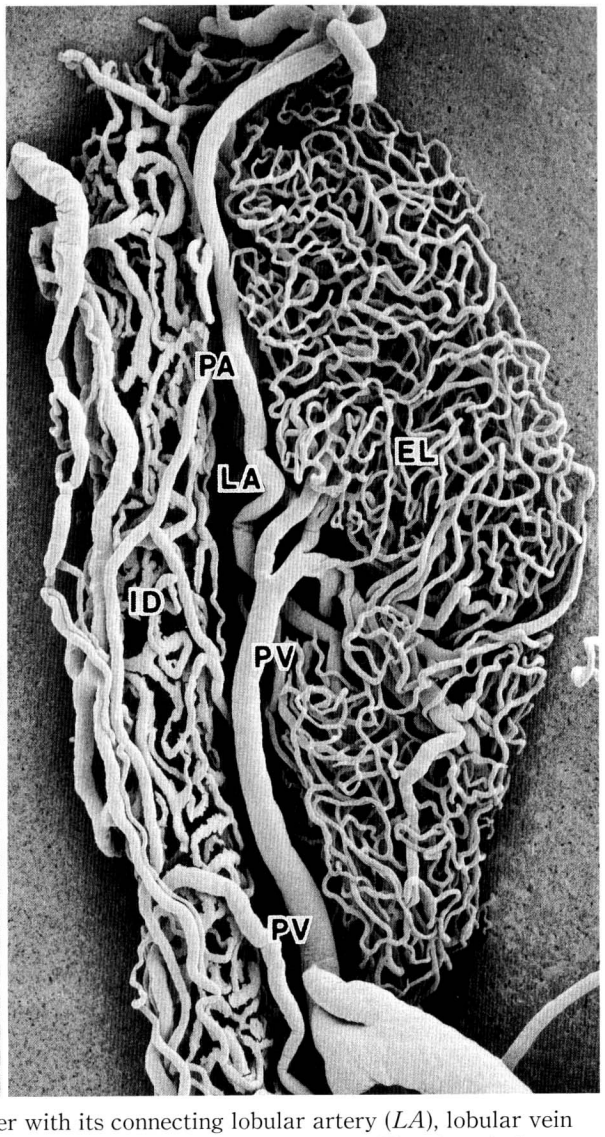

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Fig. 2. A lobular blood vascular plexus isolated together with its connecting lobular artery (*LA*), lobular vein (*LV*) and ductal plexus (*LD*) (45-year-old man). Note that the lobule is fairly independent. The ductal plexus drains at the hilus of the lobule into a branch of the lobular vein (*large arrowhead*). The *small arrowhead* indicates a rare fine capillary connection between the lobular and ductal plexuses. ×80

Fig. 3. An isolated lobular plexus (*EL*) in close association with the interlobular ductal plexus (*ID*) (75-year-old man). Note that few capillary connections are observed between the lobular and ductal plexus. ×90

(Figs. 4–11).

The islets identified by this characteristic feature in the vascular casts were usually located intralobularly (Figs. 4–10), embedded in the general capillary network of the exocrine tissue (Figs. 5–9). Only rarely did an intralobular islet expose its body to the lobular surface (Figs, 4, 8 Inset, 10). In relatively flat and thin lobules the islets were easily detectable without any intense microdissection. By surveying many such thin lobules with a light microscope, we were able to find a clearly definable insular plexus in one among seven (Fig. 8 Inset). When a lobule revealed an islet, it was usually single, but occasionally two, three or even four islets could be found in a lobule (Fig. 9).

Swellings and twistings of vascular casts presum-

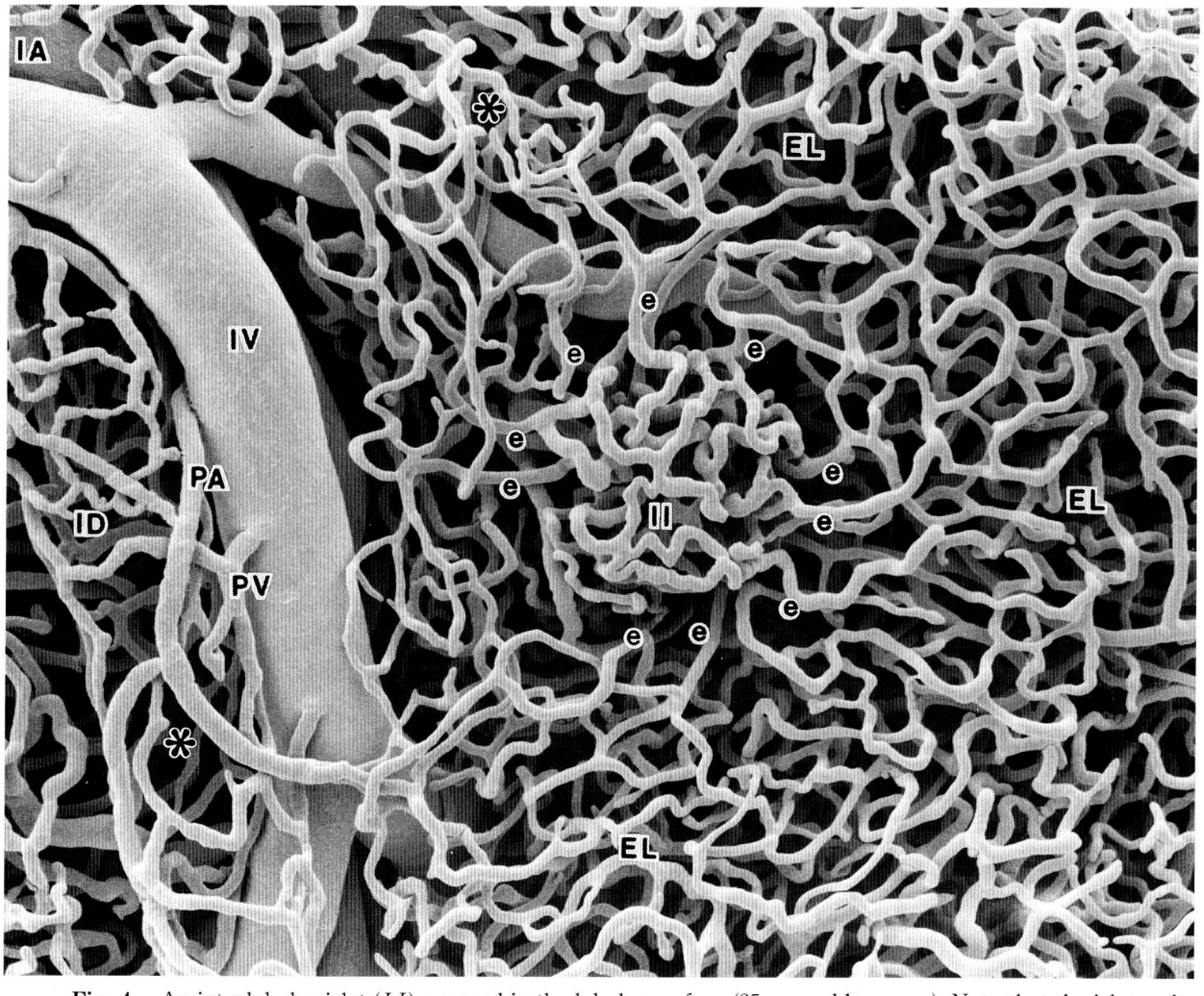

Fig. 4. An intralobular islet (*II*) exposed in the lobular surface (25-year-old woman). Note that the islet emits marked efferent vessels (*e*) which continue, as the insulo-acinar portal vessels, into adjacent lobular capillaries (*EL*). * Injection defects. ×200

ably corresponding to small islets were recognized rather frequently. Such structures occurred in lobules containing a larger, unequivocal islet or islets, as well as in lobules which apparently lacked a typical islet.

It was rare for an islet to be located interlobulary (extralobularly) or periductally, i.e., between the lobules or along the interlobular duct (Fig. 10 Inset, 11).

The intralobular islet received one to three afferent vessels (insular arterioles) from the lobular artery (Figs. 4–10). These afferent vessels entered deep into the islet and formed a conglomeration of sinusoidal capillaries (Fig. 6). In some other islets, the afferent vessels divided superficially on one pole of the islet and continued into the sinusoidal capillaries (Fig. 7). In typical cases, the afferent vessels broke up into superficial and deep branches, which supplied the islets both from the superficial and deep aspects (Fig. 10). When the islet received two or more afferent vessels, one often ran deep into the insular plexus and the other split into its superficial aspect (Fig. 8).

The peripheral or cortical capillaries of the intralobular islets issued numerous efferent vessels, i.e., the insulo-acinar portal vessels, which radiated into the capillary network in the surrounding exocrine tissues (Figs. 4–9). Some portal vessels arose deep in the islet (Figs. 6, 7, 9), others more superficially. The intralobular islets issued no efferent vessels directly draining into the veins.

The portal vessels of the intralobular islets were relatively long, straight or gently winding capillaries radiating from the islet. Without branching, they ran

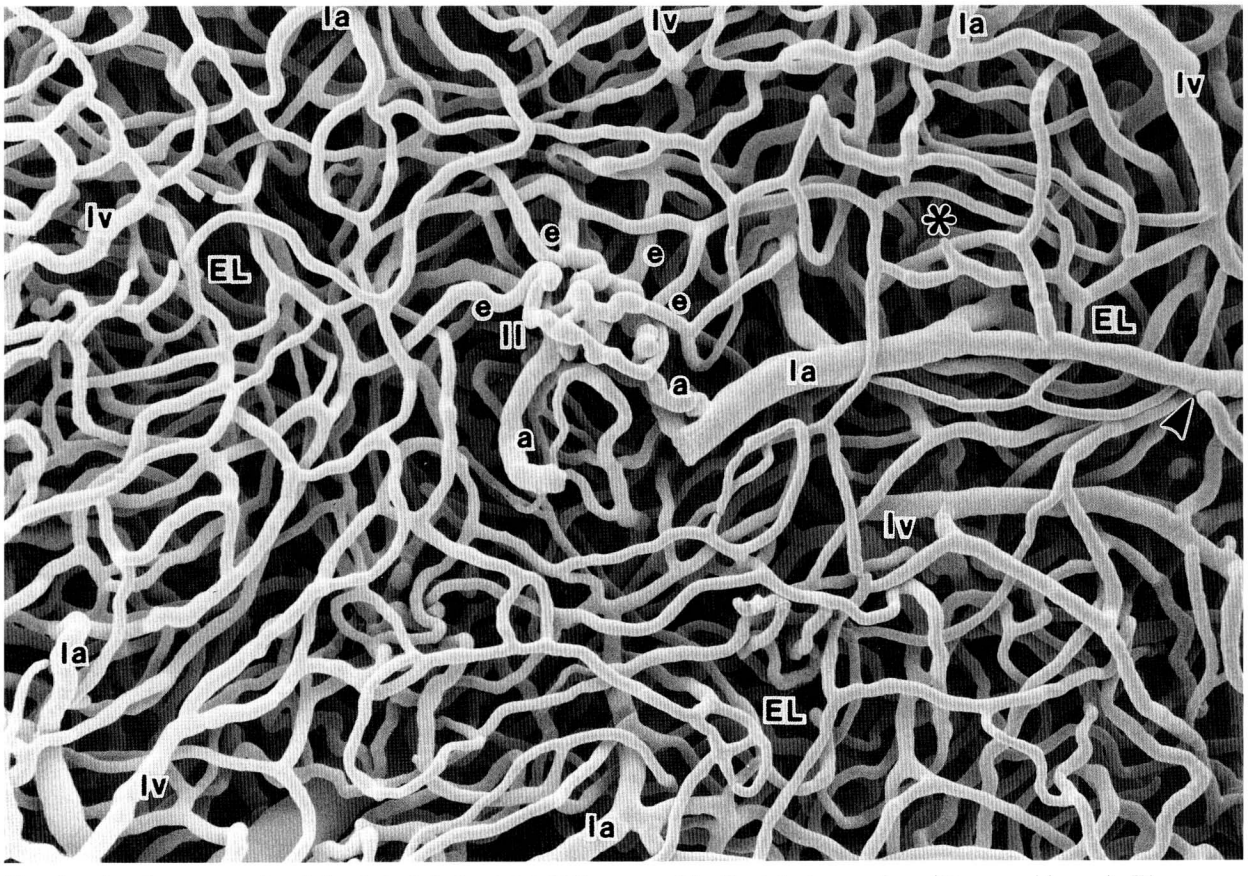

Fig. 5. Another example of the intralobular islet (*II*) exposed in the lobular surface (45-year-old man). The islet receives, though not sure because of breakage of the cast, two afferent vessels (*a*) and emits at least six insulo-acinar portal vessels (*e*) continuing to adjacent lobular capillaries (*EL*). This islet is rather small and consists of a few insular capillaries. Also note that the terminal branches of lobular arteries and veins (*la*, *lv*) run rather in parallel to each other. The *arrowhead* indicates a ring-like constriction imprinted at the origin of an arterial branch. * Injection defect. ×230

through the peri-insular zone which completely lacked the capillary network, and split into the capillary network covering the exocrine tissue (lobular capillaries) (Figs. 4–9). The portal vessels were characteristically slender, being never thicker than the capillaries in the islet and as thick as or slightly thicker than the lobular capillaries (Figs. 4–10).

The number of the portal vessels varied widely among islets. Generally larger islets possessed a larger number of portal vessels. Larger islets exceeding 200 μm in diameter issued 30 or more portal vessels, whereas a small islet consisting of a few capillary loops issued three to seven portal vessels.

Usually, a part of the lobular capillary network was supplied with the portal vessels of the islet, while the remaining part directly received lobular arteries; both portions of the lobular capillaries were drained by the lobular veins (Fig. 5). On rare occasions, the entire extent of the lobular capillary network was supplied with the portal vessels (Fig. 10). In these latter cases, the lobular artery or arteries took the exclusive role as the afferent vessel for the islet (Fig. 10).

The afferent vessels of intralobular islets sometimes showed ring-like or V-shaped constrictions (Fig. 6 Inset). No marked constrictions were noted in the insulo-acinar portal vessels.

Interlobular islets and their vascular connections

The human pancreas only occasionally revealed islets located in the interlobular connective tissue. The interlobular (extralobular) islets received one or more afferent vessels from the interlobular or periductal arteries (Figs. 10 Inset, 11). The afferent arterioles penetrated deep into the islets to form a con-

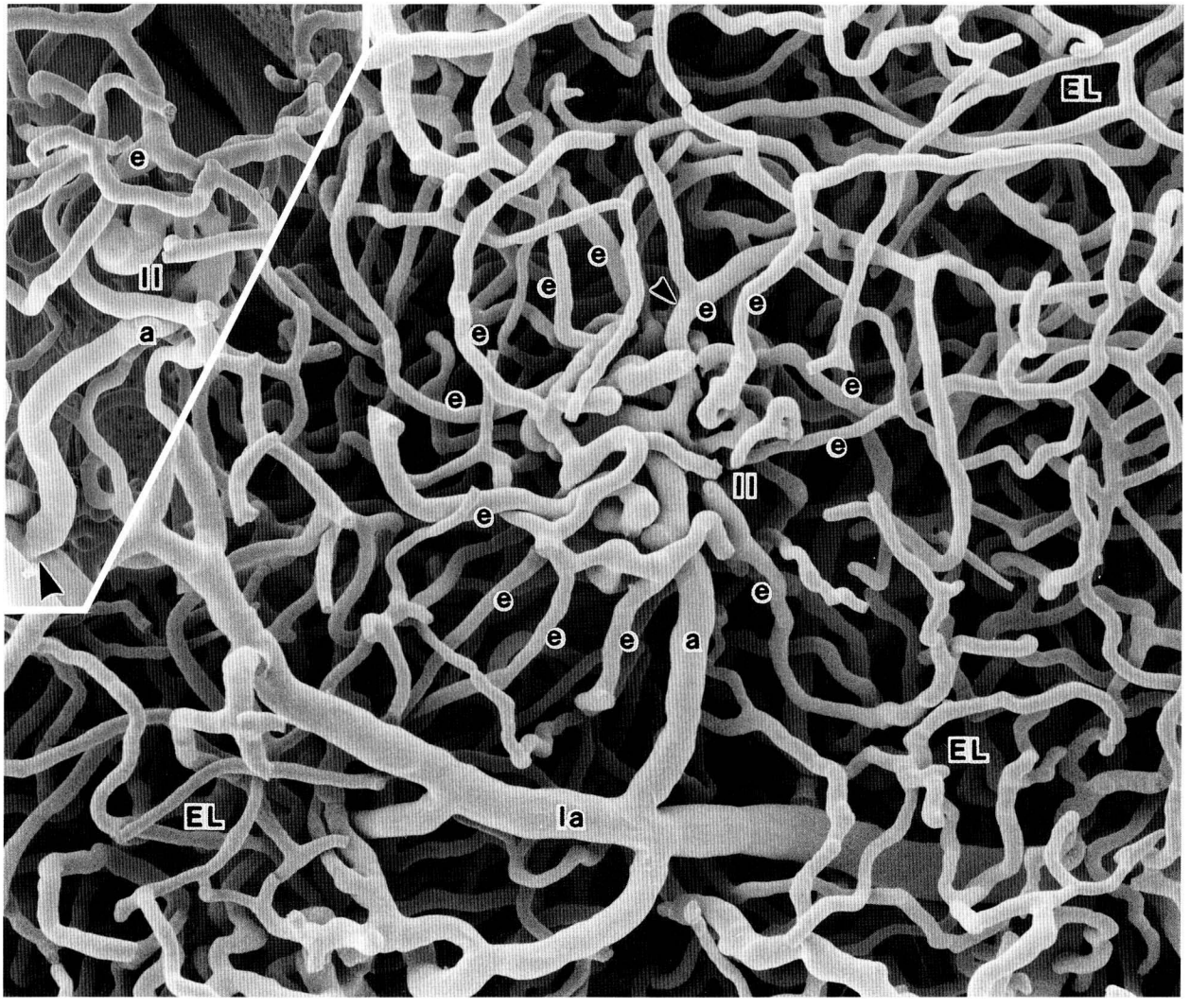

Fig. 6. An intralobular islet (*II*) located deep in the lobule and exposed by microdissection (45-year-old man). Note that the afferent vessel (*a*) runs deep into the islet, and that the islet emits from its surface the insulo-acinar portal vessels (*e*) continuing adjacent lobular capillaries (*EL*). One of the efferent vessels (*arrowhead*) arises in a deep portion of the islet. **Inset** shows a marked V-shaped constriction (*arrowhead*) imprinted at the origin of the afferent vessel (*a*) of an intralobular islet (*II*) (45-year-old man). ×280, Inset: ×310

glomeration of sinusoidal capillaries. This deep capillary plexus was surrounded and drained by a thin network of fine capillaries (outer capillary meshwork) (Figs. 10 Inset, 11). This marginal network, in turn, issued efferent vessels which were directly continuous with the interlobular or periductal veins (Figs. 10 Inset, 11). No marked constrictions were noted in the efferent vessels of the interlobular islets. Neither capillary connections nor portal routes were noted between these islets and the ducts.

Interlobular vascular beds

The capillary plexus in the interlobular tissue spaces (interlobular capillary plexus) was very coarse, being intercalated between the interlobular or periductal arteries and veins. This plexus was occasionally continuous with the lobular or periductal plexus (Fig. 1), and sometimes was organized into tubular structures surrounding interlobular lymphatics. They were also sometimes organized, as the vasa vasorum, into a columnar structure surrounding the interlobular arteries or veins.

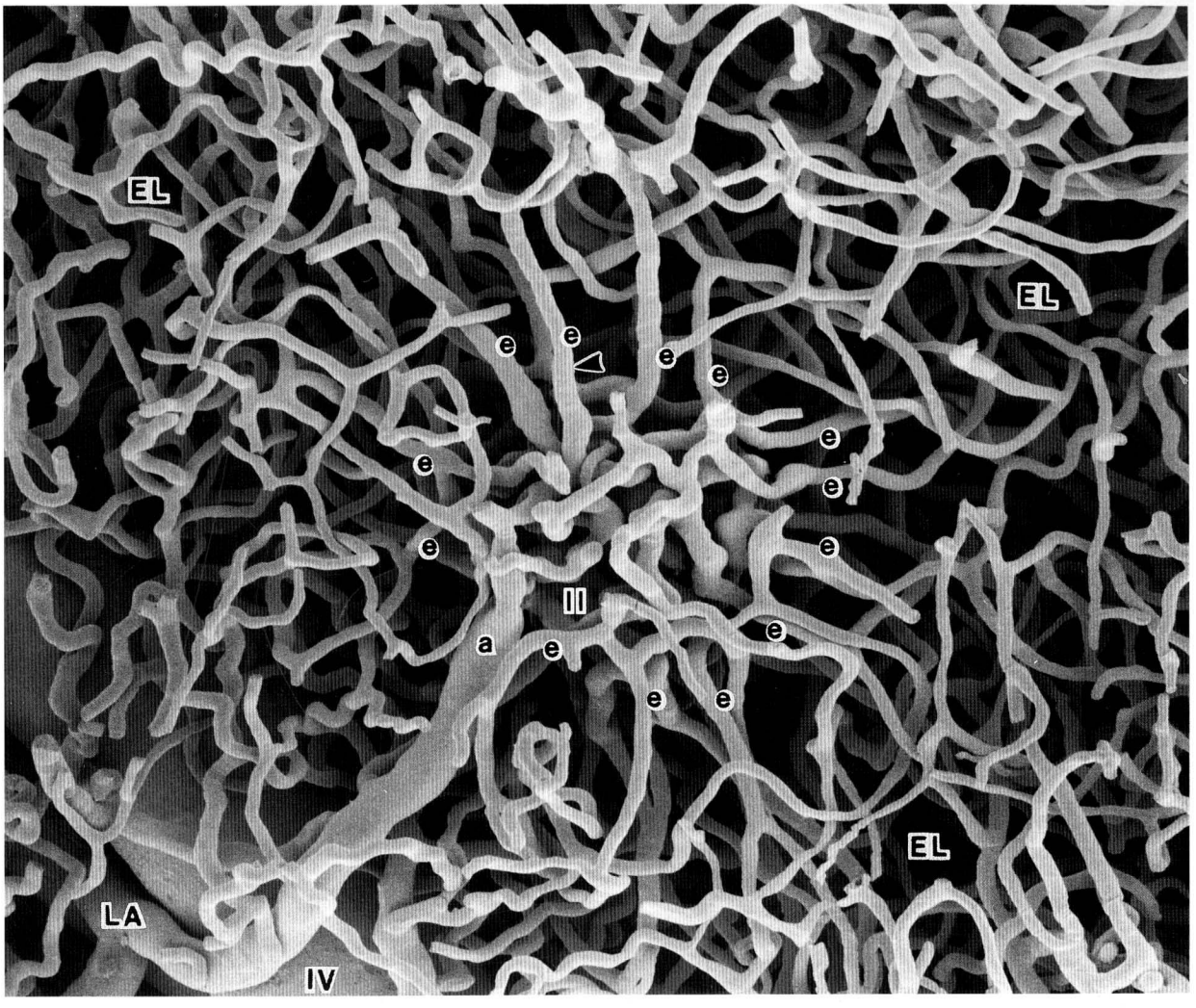

Fig. 7. An intralobular islet (*II*) exposed by microdissection (75-year-old man). Note that the afferent vessel (*a*) divides at one pole of the islet into the insular capillaries, and that the efferent vessels (*e*) continue, as the insulo-acinar portal vessels, into the adjacent lobular capillaries (*EL*). The *arrowhead* indicates an efferent vessel with an origin deep in the islet. ×280

DISCUSSION

This paper demonstrates that in the human pancreas, most of the endocrine islets are located intralobularly, i.e., in the exocrine lobules, and receive a proper afferent arteriole. The islets emit efferent vessels. As these vessels radiate into the lobular capillaries covering the exocrine acini and intralobular ducts, they therefore deserve the name of insulo-acinar portal vessels.

The portal connections between the intralobular islets and exocrine tissue in the human pancreas are quite similar to the state in the rhesus monkey pancreas, which we previously demonstrated by scanning electron microscopy of the vascular casts (FUJITA and MURAKAMI, 1973). Little information has hitherto been available concerning the human insulo-acinar portal vessels. WHARTON (1932) and YAGINUMA et al. (1981) described by light microscopy of India ink-injected and serially sectioned tissue specimens that the human endocrine islets issued small efferent vessels which passed into the acinar tissue.

Occurrence of the insulo-acinar portal vessels has been demonstrated in certain animals, including the horse, rabbit, dog, rat and mouse, by light microscopy

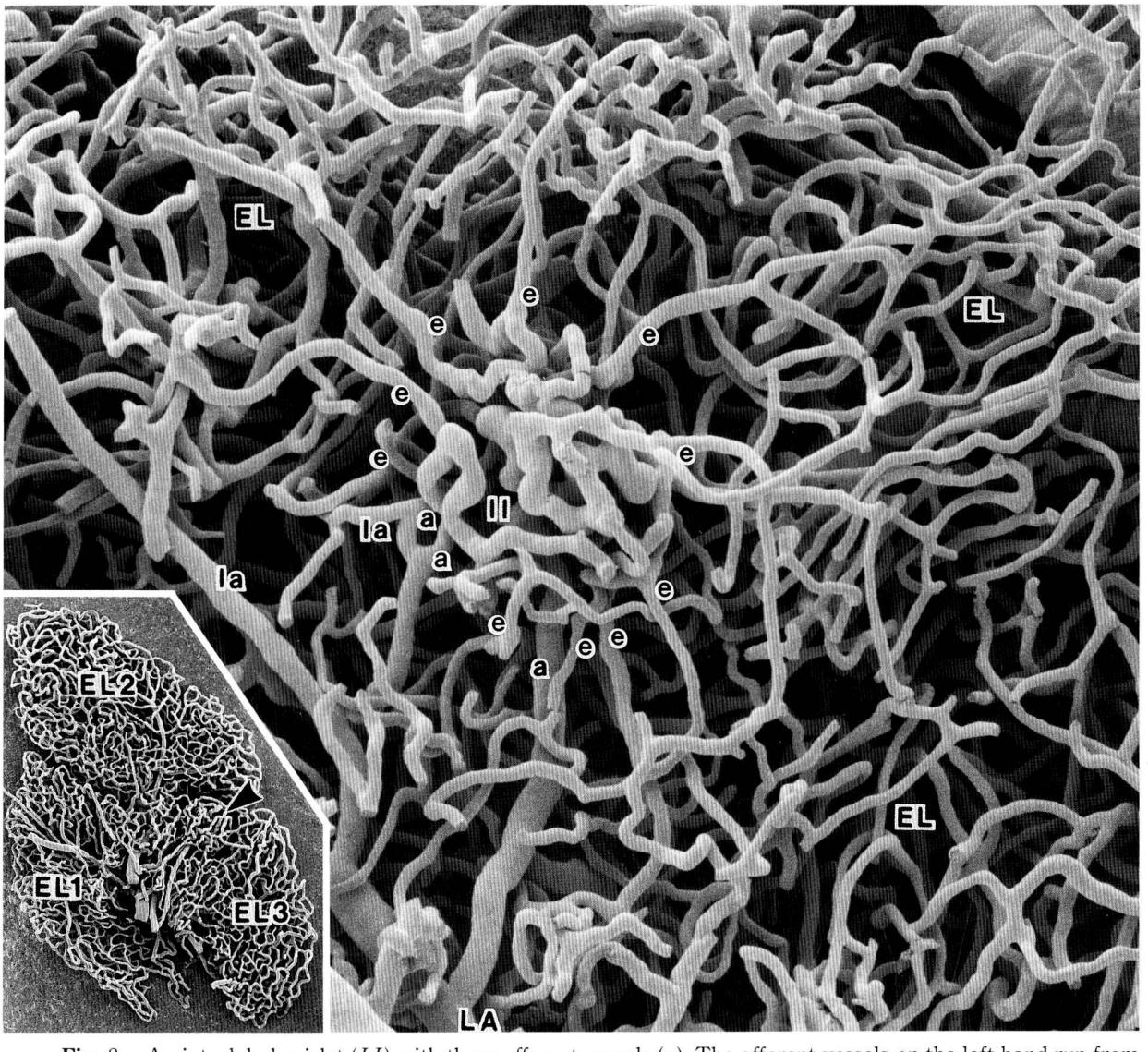

Fig. 8. An intralobular islet (*II*) with three afferent vessels (*a*). The afferent vessels on the left hand run from the superficial aspect into the insular capillaries, while the right-hand one runs deep into the islet. This islet also emits many insulo-acinar portal vessels (*e*) continuous with the adjacent lobular capillaries (*EL*). **Inset** shows an isolated cluster of three lobules (*EL1–EL3*) (25-year-old woman). Note in this inset that only the *EL3* lobule contains an islet (*arrowhead*). ×250, Inset: ×40

of tissue sections, intravital microscopy of living tissues, scanning electron microscopy of vascular casts and other methods (BECK and BERG, 1931; WHARTON, 1932; THIEL, 1954; MCCUSKEY and CHAPMAN, 1969; FUJITA, 1973; FUJITA and WATANABE, 1973; FUJITA et al., 1976; BONNER-WEIR and ORCI, 1982; OHTANI, 1983; NISHINO, 1984; SYED ALI, 1984; OHTANI et al., 1986). Occurrence of the insulo-acinar portal vessels has been demonstrated even in lower vertebrates such as snakes (SYED ALI et al., 1991).

However, some authors who mainly studied the rat and mouse by intravital microscope methods, contended that the efferent vessels preferentially drained into veins (BRUNFELDT et al., 1958; BUNNAG et al., 1963). BONNER-WEIR and ORCI (1982) studied the rat by scanning of the vascular casts and described that medium- and large-sized islets preferentially had direct venous drainages, while small-sized islets issued insulo-acinar portal vessels. OHTANI et al. (1986) made a scanning study of rat pancreatic casts and

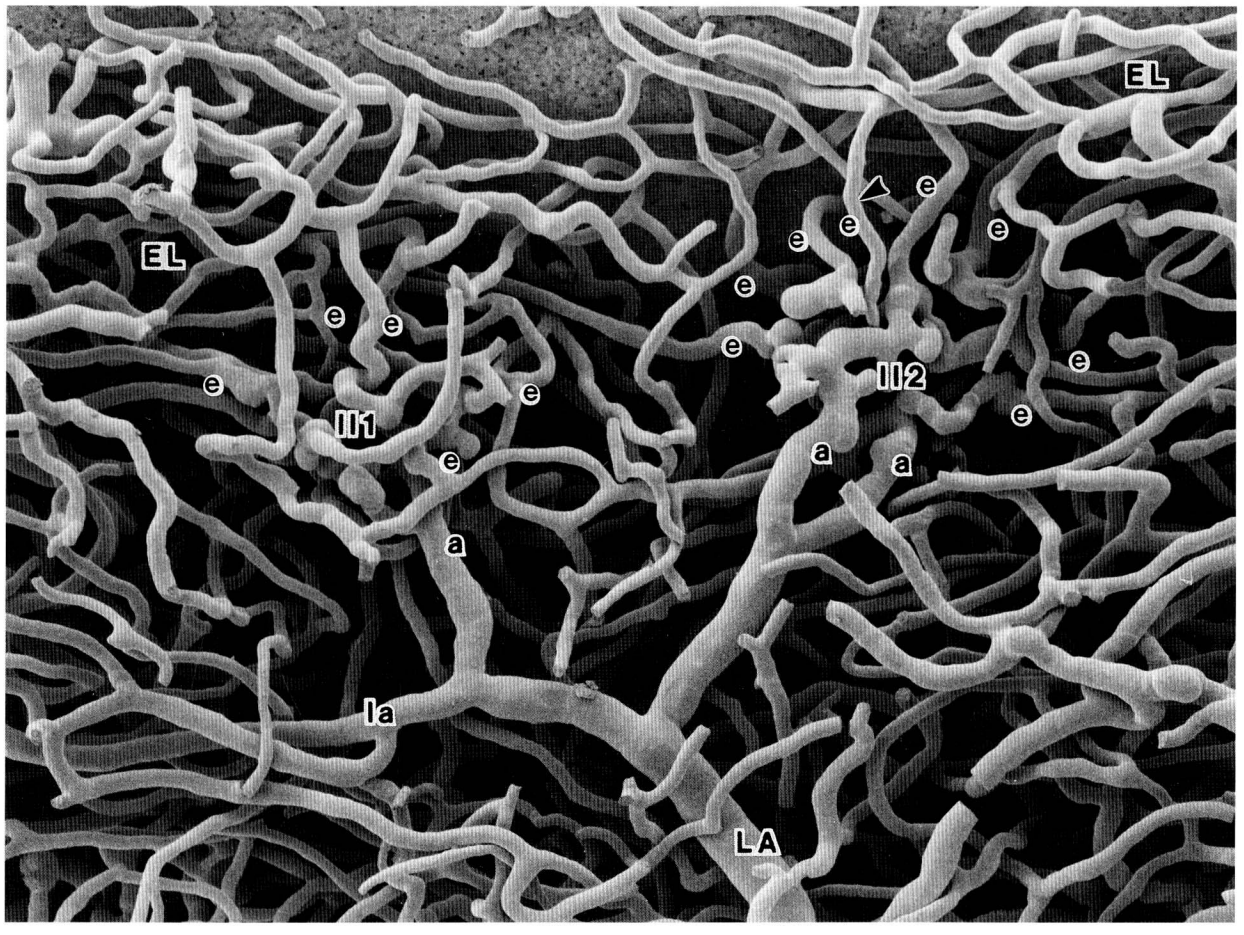

Fig. 9. Two intralobular islets (*II1*, *II2*) as found in the same lobule (45-year-old man). The *II2* islet receives two afferent vessels (*a*), and one of its efferent vessels (*arrowhead*) arises deep in the islet. Even in these islets, all of the efferent vessels (*e*) (including that indicated by the *arrowhead*) continue, as the insulo-acinar portal vessels, into the adjacent lobular capillaries (*EL*). ×280

contended that all islets issued insulo-acinar portal vessels, though about 60% of the islets additionally possessed an emissary vein or veins leading directly into interlobular veins. Such a coexistence of portal and venous drainages had been illustrated in the islets of the mouse by BECK and BERG (1931).

This paper shows that in the human pancreas, a small number of endocrine islets are located interlobularly or extralobularly, and that these islets are capsulated by a network of thin capillaries, which issues venous vessels directly continuous with the interlobular or periductal veins. One idea proposed is that this capsular network of the interlobular islets is homologous with the lobular capillary bed for the intralobular islets. In the interlobular islets, thus, the portal vessels may be said to exist between the core plexus of sinusoidal capillaries and the capsular network of thin capillaries. This is schematically illustrated in Figure 12.

Recently, we reinvestigated pancreatic vascular casts of the mouse, rat, guinea pig, rabbit, cat, dog, pig with special reference to the occurrence of intra- and interlobular islets and their microcirculation. The species differences in these regards were conspicuous. In the mouse and rat, many islets were located interlobularly along the excretory ducts, and drained *via* their surface network of fine capillaries (similar to the human situation shown in the present study) into the interlobular or periductal veins. We confirmed, in the mouse and rat, that the intralobular islets usually had both drainages into the portal vessels and into the intralobular veins (see below). In the guinea pig, many islets were located interlobularly, and drained *via* their surface capillary network

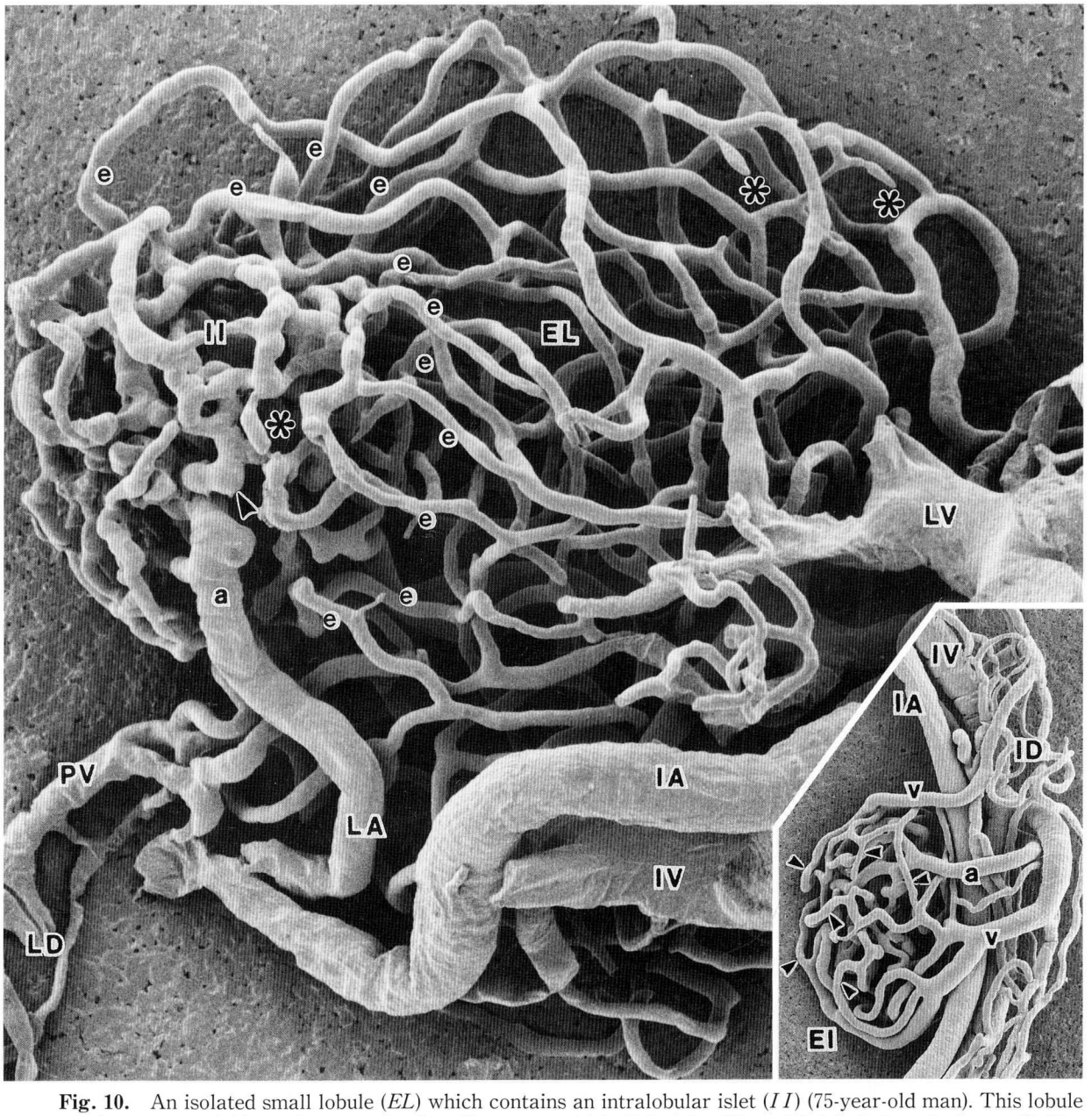

Fig. 10. An isolated small lobule (*EL*) which contains an intralobular islet (*II*) (75-year-old man). This lobule receives no arterial branch except for the afferent vessel (*a*) of the islet. Thus, this lobule is entirely supplied by the efferent vessels (*e*) of the islet. *Arrowhead* indicates a superficial branch of the afferent vessel. **Inset** shows an extralobular islet (*EI*) which is characterized by an additional thin network of fine capillaries (*arrowheads*) on its surface (25-year-old woman). * Injection defects. ×300, Inset: ×150

into the interlobular or periductal veins; the intralobular islets usually issued portal vessels. In the rabbit, cat, dog, pig, and cattle, interlobular islets were hardly encountered; islets were constantly intralobular in location and issued typical portal vessels. The dog particularly resembled the human in the pattern of the insulo-acinar portal system and the microvascular organization within the islet. The details of these findings will be reported elsewhere.

The insulo-acinar portal system conveys high concentrations of insular hormones to the exocrine acini, and presumably regulates the secretory activities of the acini, as has been extensively reviewed in various animals (FUJITA and WATANABE, 1973; FUJITA and

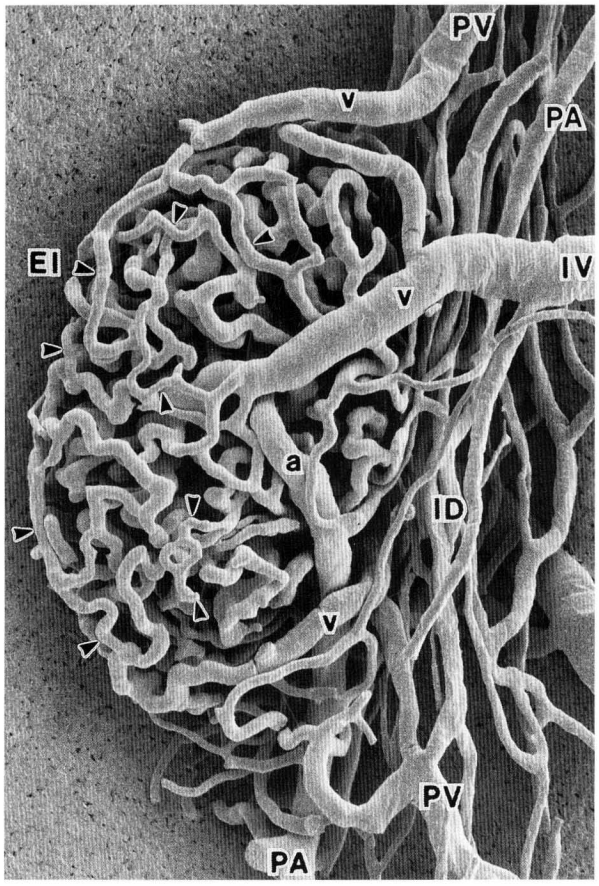

Fig. 11. An extralobular islet (*EI*). Note that this islet is provided with a set of fine capillaries (*arrowheads*), which receives the sinusoidal capillaries of the islet and confluences into the emissary veins (*v*) finally continuous with the periductal (*PV*) or interlobular (*IV*) veins. (Also see Figure 10 Inset). ×250

KOBAYASHI, 1979; HENDERSON et al., 1981; HENDERSON, 1983; TRIMBLE et al., 1985; OHTANI, 1988). In the human pancreas, as described above, one out of every seven thin lobules contained one to four (usually, one) islets clearly identifiable, under the light microscope, by their vascular pattern. This does not exclude the possibility that six of the seven lobules were lacking in islets, because some small globules of islet capillaries may have been overlooked. Furthermore, thicker lobules likely possess their islets more constantly. Nevertheless, it is reasonable to say that a considerable number of lobules are devoid of any islet in the human pancreas. Moreover, the range of the portal vessels was limited, and it was rare that they covered the entire exocrine lobules. It is thus suggested that in humans, the insular control over the exocrine pancreas generally is valid in restricted areas of the lobule.

Based upon his light microscopic observation of serial sections, WHARTON (1932) illustrated ten islets in a human pancreatic lobule. In our cast specimens, a lobule contained four islets at most. This difference may be due to the possibility that we failed to find many islets, especially small ones, in large, thick lobules.

In spite of the limited distribution and range of the insulo-acinar portal vessels, our experimental data in the rat pancreas support the possibility that lobular blood may preferentially flow through the portal route. We performed arterial injections of insufficient amounts of India ink or resin, and found that the insulo-acinar portal route was filled with the injected material more promptly than the usual route from lobular arteries. Details of this finding in the rat will be reported elsewhere (MIYAKE et al., 1992).

In our previous casting of the monkey pancreas, marked circular constrictions were noticed in the insulo-acinar portal vessels (FUJITA and MURAKAMI, 1973). None of such constrictions could be found in the human insulo-acinar portal vessels as here replicated. This may possibly be because the specimens were obtained at autopsy and injected with resin about 3 h or longer after death. Thus, little information, including the histological data, has been available on the mural structures of the human insulo-acinar portal vessels. The possibility that these vessels, like the efferent vessels of the kidney glomeruli (MURAKAMI, 1972), may be provided with smooth muscles regulating the blood flow from the islet to the lobular capillaries remains to be investigated. SYED ALI (1984) replicated some circular constrictions in cat insulo-acinar portal vessels and suggested that this structure might reflect the occurrence of pericytes as sphincters regulating the flow of blood from the islet to the exocrine pancreas.

This paper demonstrates that, for the human islets, no rule can be found as to whether afferent vessels are primarily connected to the deep or superficial portion of the islet. This indecisive pattern of islet microcirculation resembles the situation in the dog (FUJITA et al., 1976; MURAKAMI, unpublished data). In certain animal species, the pattern of insular microcirculation is known to be more regular. In the horse and rhesus monkey, the afferent vessels enter deep into the core of the islet, while the efferent vessels emerge from the cortical portion of the islet (FUJITA, 1973; FUJITA and MURAKAMI, 1973; FUJITA et al., 1976). In contrast, islets in the rabbit, rat and mouse receive afferent vessels in their superficial layer and emit efferent vessels from their deeper portion (OHTANI et al., 1986; MURAKAMI, unpublished data). FUJITA (1973)

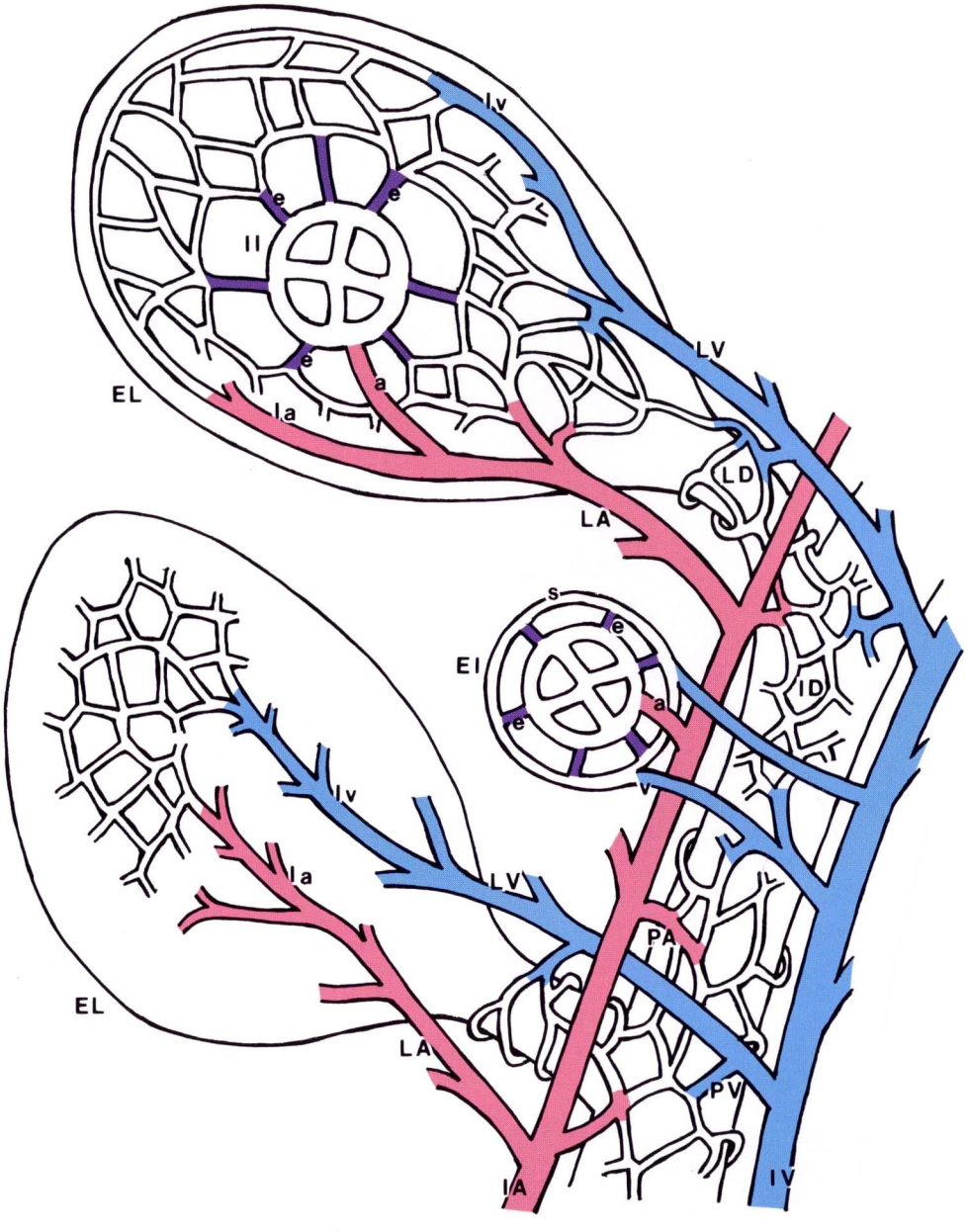

Fig. 12. A diagram showing the vascular arrangements of the human pancreas. From the top to the bottom are shown a lobule containing an islet, an extralobular (periductal) islet, and a lobule lacking in an islet. An interlobular duct is illustrated on the right hand. For abbreviations, see under Figure 1.

proposed a rule that blood in the islet flows first to the area of A and D cells, then to the area of B cells, and suggested that the B cells' release of insulin might be regulated by glucagon and somatostatin issued from A and D cells more effectively than otherwise by this microcirculatory design. Actually the horse and rhesus monkey possess A and D cells in the core of the islet, and B cells in the cortex; the rabbit and murine islets possess the well known mantle consisting of A and D cells. In humans, as in dogs, A, B and D cells are rather irregularly intermingled within the islets. This may account for the indecisive pattern of blood vessels in these species.

The rule of the intrainsular circulation has been examined in the rat. BONNER-WEIR and ORCI (1982) claimed that the blood, inversely to the "rule", reached the islet center first and then flowed to the A-D cell mantle. OHTANI et al. (1986), however, confirmed by intravital microscopy of the pancreas injected with a fluorescent tracer, that blood flowed from the mantle to the core, to be later drained into efferent vessels. Our recent reinvestigation of rat vascular casts under the scanning electron microscope (MURAKAMI and FUJITA, 1992) supports this result by OHTANI et al. (1986).

This paper moreover shows that in the human pancreas, the capillary plexus of the exocrine lobules and extralobular secretory ducts have little communication. This indicates that the capillary plexuses of the exocrine lobules and extralobular secretory ducts are independent of each other in view of blood supply. Within the lobule, in contrast, the exocrine acini and their connecting intercalated and intralobular secretory ducts are commonly supplied.

LIFSON and LASSA (1981) arterially injected silicone latex, India ink, hematoxylin or microsphere into rabbit pancreas and traced it under the light microscope. Noticing that the ductal plexus received blood from the exocrine acini, they conceived of the following route: islet capillaries—acinar (lobular) capillaries—ductal plexuses. In our human samples, however, few channels were observed between the capillary plexus of the exocrine lobules and that of the extralobular ducts. By scanning microscopy of replicated rat and rabbit pancreata, OHTANI (1983, 1988) reported that the islets sometimes emitted efferent vessels continuous to the periductal capillary plexus. This "insulo-ductal portal system" was not identified in our human samples.

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Prof. Takuro Murakami
Department of Anatomy
Okayama University School of Medicine
2-5-1 Shikata-cho, Okayama
700 Japan

村 上 宅 郎
700 岡山市鹿田町 2-5-1
岡山大学医学部
第二解剖学教室